Wind energy and SAR wind mapping

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workshops

Wind energy and SAR wind mapping

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Abstract

Online processing of SAR to wind maps is ongoing, and the series of wind maps are used for investigation of offshore wind resources. In wind energy the siting of a wind farm is dependent upon reliable information about the wind climate within the area of interest. Offshore this information is hard to retrieve as it is costly to install and maintain offshore meteorological masts and very few reliable data sets exits. Typically a meteorological mast is erected for the purpose of calculating the wind resource. An alternative approach using satellite SAR images has been developed and tested. The results are fairly good and the method is growing into an applied routine. Results from an in-depth study in the Scandinavia Seas will be presented. In this offshore area around 15 offshore wind farms are operating and more are in construction. Thus the study is focussed on an area with major offshore wind power capacity.

Workshop presentation

Higher level

Last modified: 07.05.06

Charlotte Bay Hasager
Merete Bruun Christiansen

Wind energy and SAR wind mapping

Wind Energy Department
Risoe National Laboratory DTU
Denmark

Courtesy: DONG energy, Denmark

Wind power trend

Wind ressource – SAR

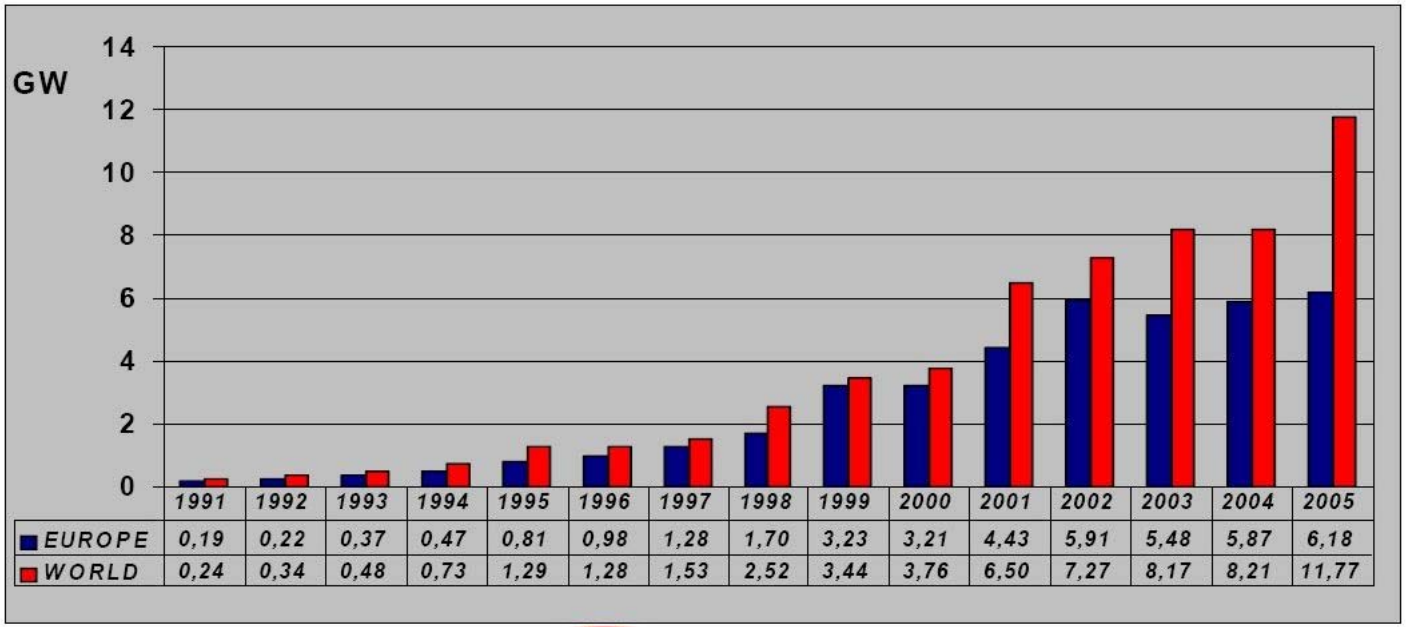
Wake - SAR

20 year prediction

EWEA

25 YEARS POWERING CHANGE

Global wind power market growth



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
EUROPE	0,19	0,22	0,37	0,47	0,81	0,98	1,28	1,70	3,23	3,21	4,43	5,91	5,48	5,87	6,18
WORLD	0,24	0,34	0,48	0,73	1,29	1,28	1,53	2,52	3,44	3,76	6,50	7,27	8,17	8,21	11,77

Average Annual Growth Rates

Europe
1995-2000 31.7%,
2000-2005 14.0%

World
1995-2000 23.8%,
2000-2005 25.6%

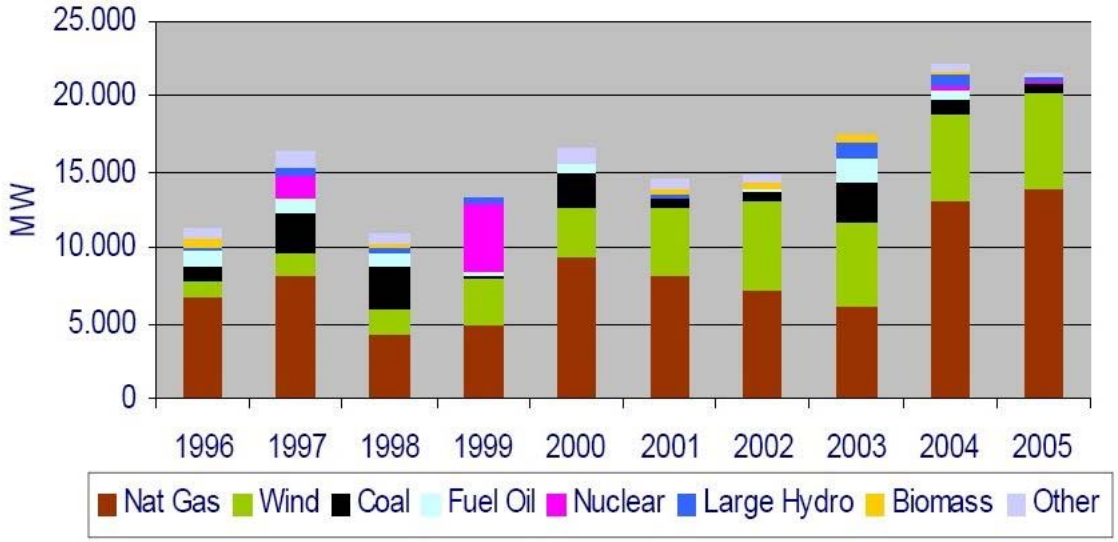
Source: EWEA, GWEC

EWEA

25 YEARS POWERING CHANGE

EU capacity installations 1996-2005 (MW)

New installed capacity EU-15 1996-2005



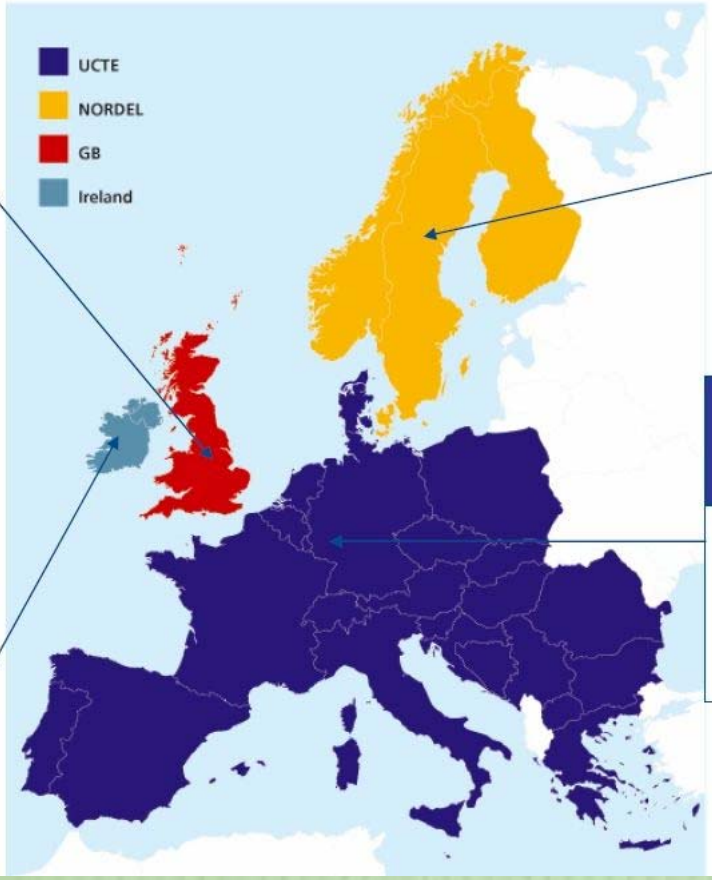
2006 : new gas: 8.5 GW new wind: 7.5 GW

Source: Platts/EWEA

EWEA

25 YEARS POWERING CHANGE

Europe: Distribution of wind power capacity (2006)



GB
76.3 GW
Wind:
2 GW
3%

Nordel
93 GW
Wind:
1.7 GW
2%

UCTE
605 GW
Wind:
44 GW
7%

Ireland
7.6 GW
Wind:
0.75 GW
10%

Total 782 GW

Wind 48.5 GW (6%)

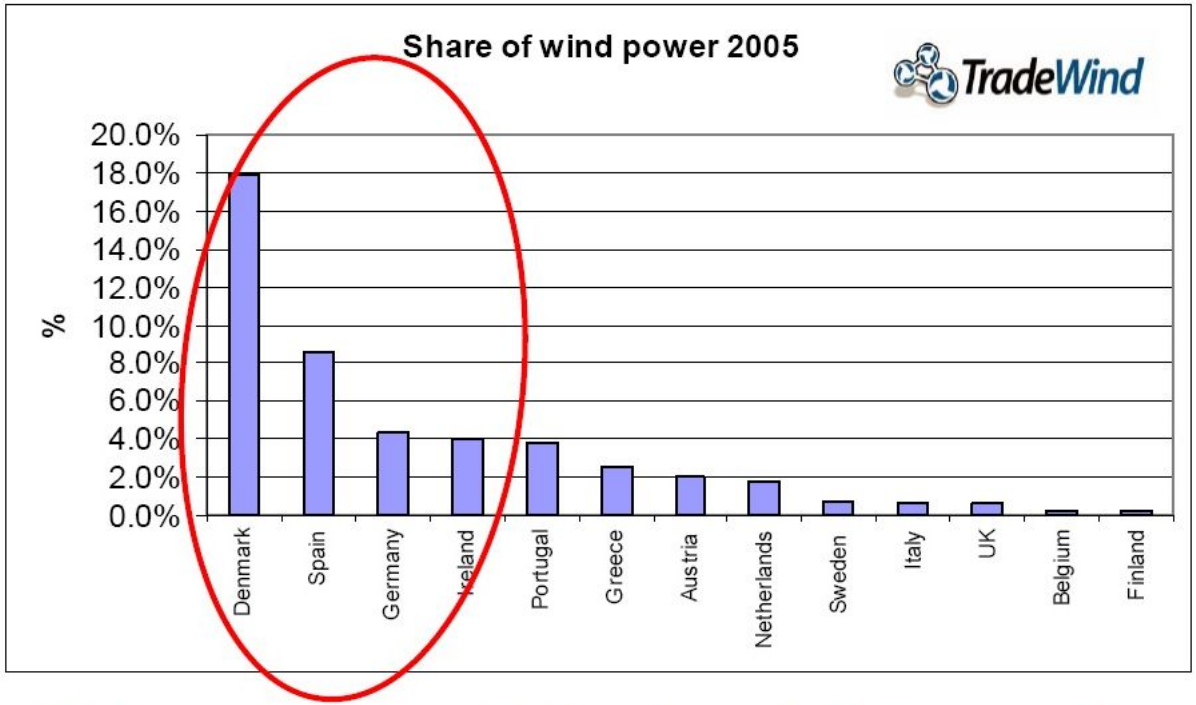
EU decision

20% renewable by 2020

EWEA

25 YEARS POWERING CHANGE

European spread in wind energy penetration 2005



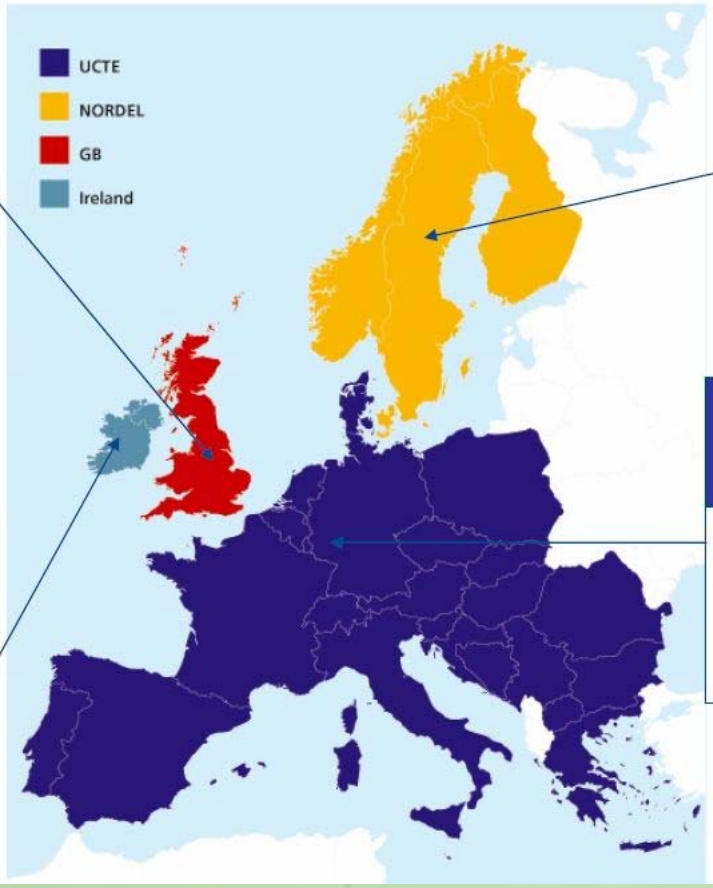
Wind energy production as fraction of gross electricity consumption
(not corrected for average wind year)

EWEA

25 YEARS POWERING CHANGE

TradeWind

Europe: Distribution of wind power capacity (2030)



GB

Wind:
18 GW
17%

Nordel

Wind:
21 GW
20%

UCTE

Wind:
258 GW
30+%

Ireland

Wind:
5 GW
30%

Wind 306 GW

EWEA

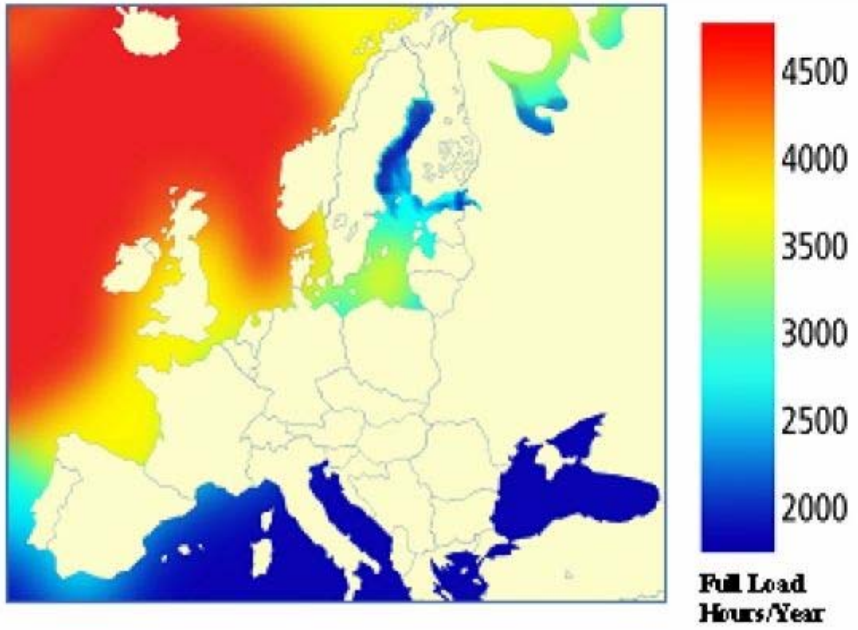
25 YEARS POWERING CHANGE

Europe's wind resource

EWEA target

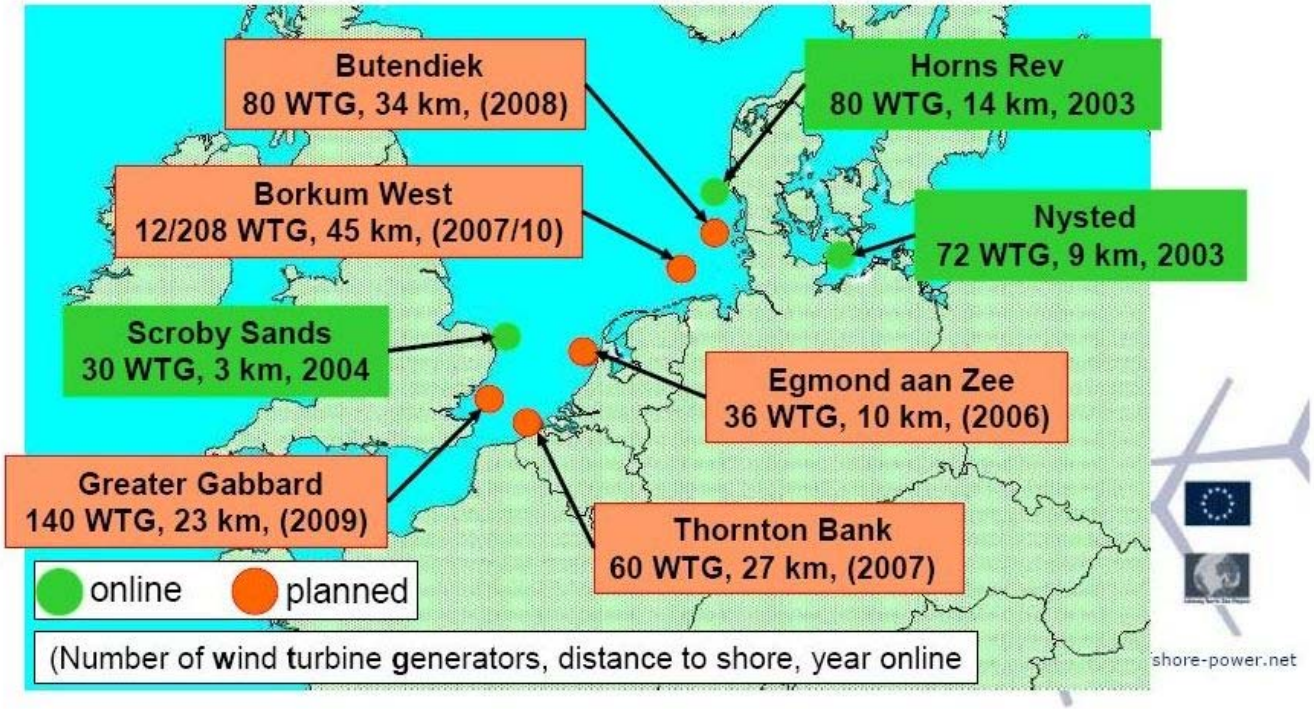
Europe wind power capacity 2030

150 GW offshore
150 GW on land



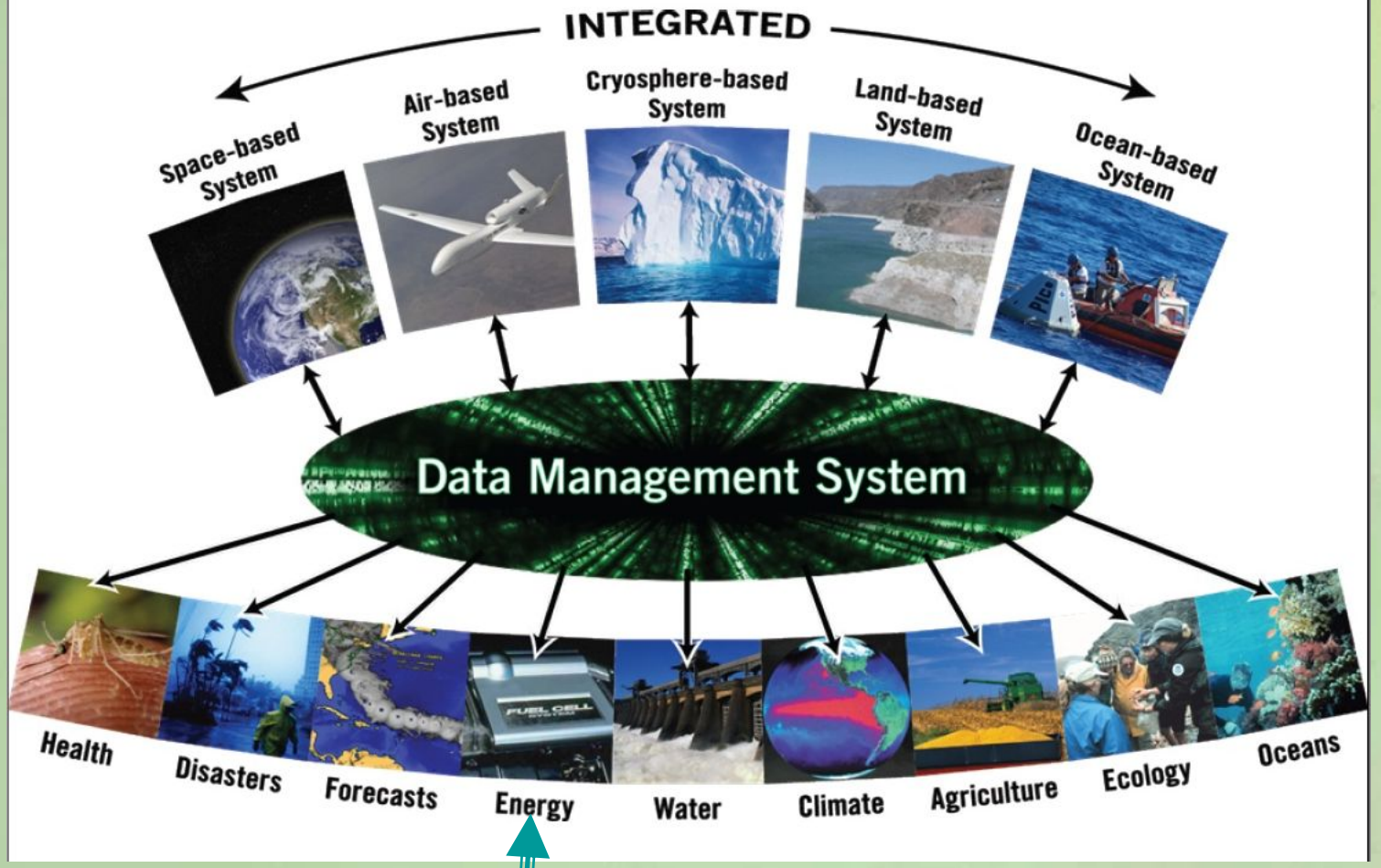
Pushing Offshore Wind Energy Regions (POWER)

Case Study: Analysed Offshore Wind Farms
by dena, Deutsche Windguard and University of Groningen



Horns Rev, Elsam A/S

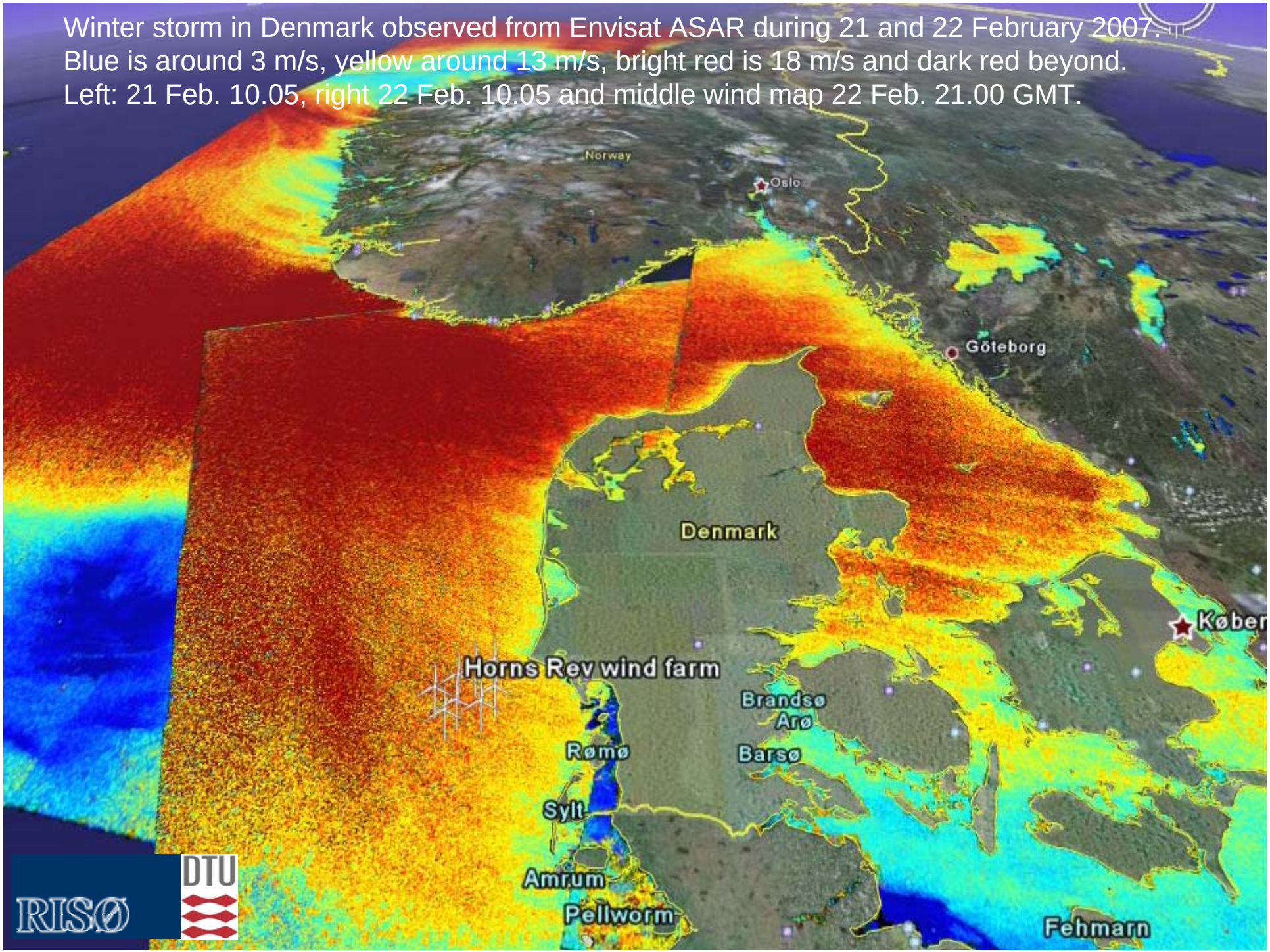
GEOSS Concept



For offshore wind projects, which type of data are you interested in?

1. Wind speed and directions
2. Vertical wind profiles
3. Wind statistics
4. Wind shear
5. Forecast of meteorological conditions
6. Monitoring of meteorological conditions
7. Wave heights

http://www.geoss-ecp.org


Winter storm in Denmark observed from Envisat ASAR during 21 and 22 February 2007.
Blue is around 3 m/s, yellow around 13 m/s, bright red is 18 m/s and dark red beyond.
Left: 21 Feb. 10.05, right 22 Feb. 10.05 and middle wind map 22 Feb. 21.00 GMT.
Norway
Oslo
Göteborg
Denmark
Horns Rev wind farm
Brandsø
Arø
Barsø
Rømø
Sylt
Amrum
Pellworm
Fehmarn
RISØ
DTU

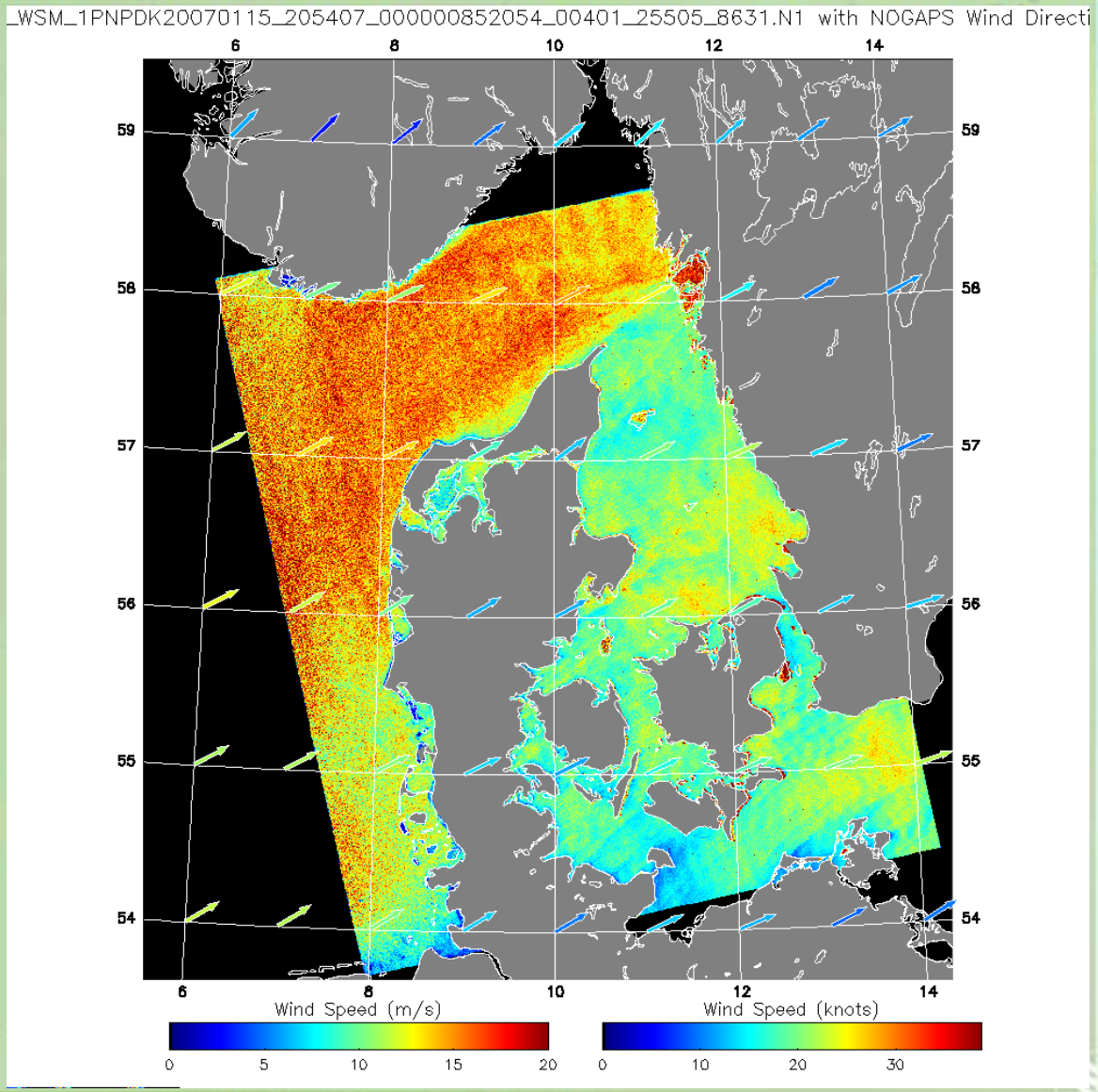
Envisat ASAR images daily from ESA for the Scandia SAR project

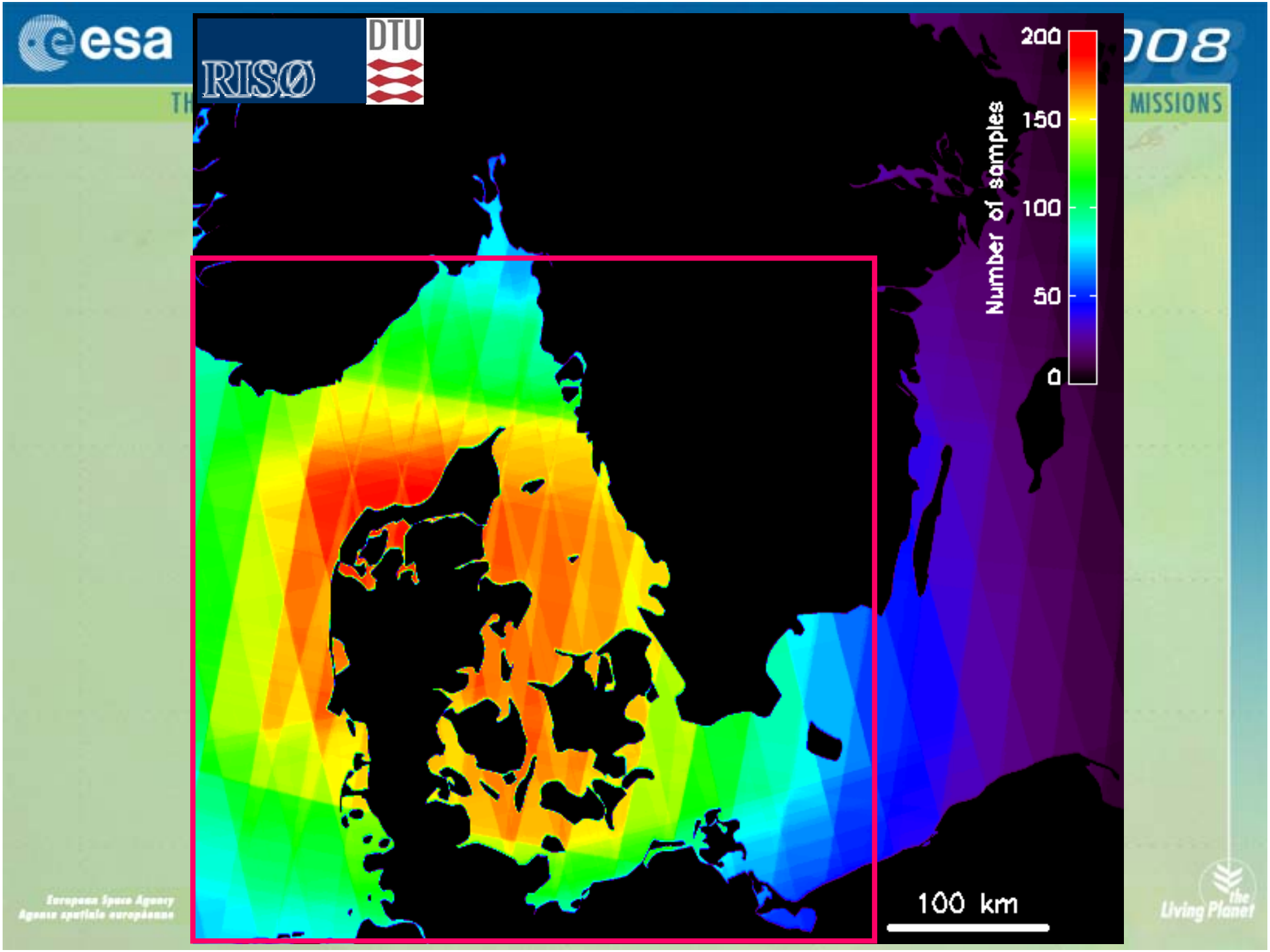
ANSWRS tool (JHU/APL) Frank Monaldo and Don Thompson

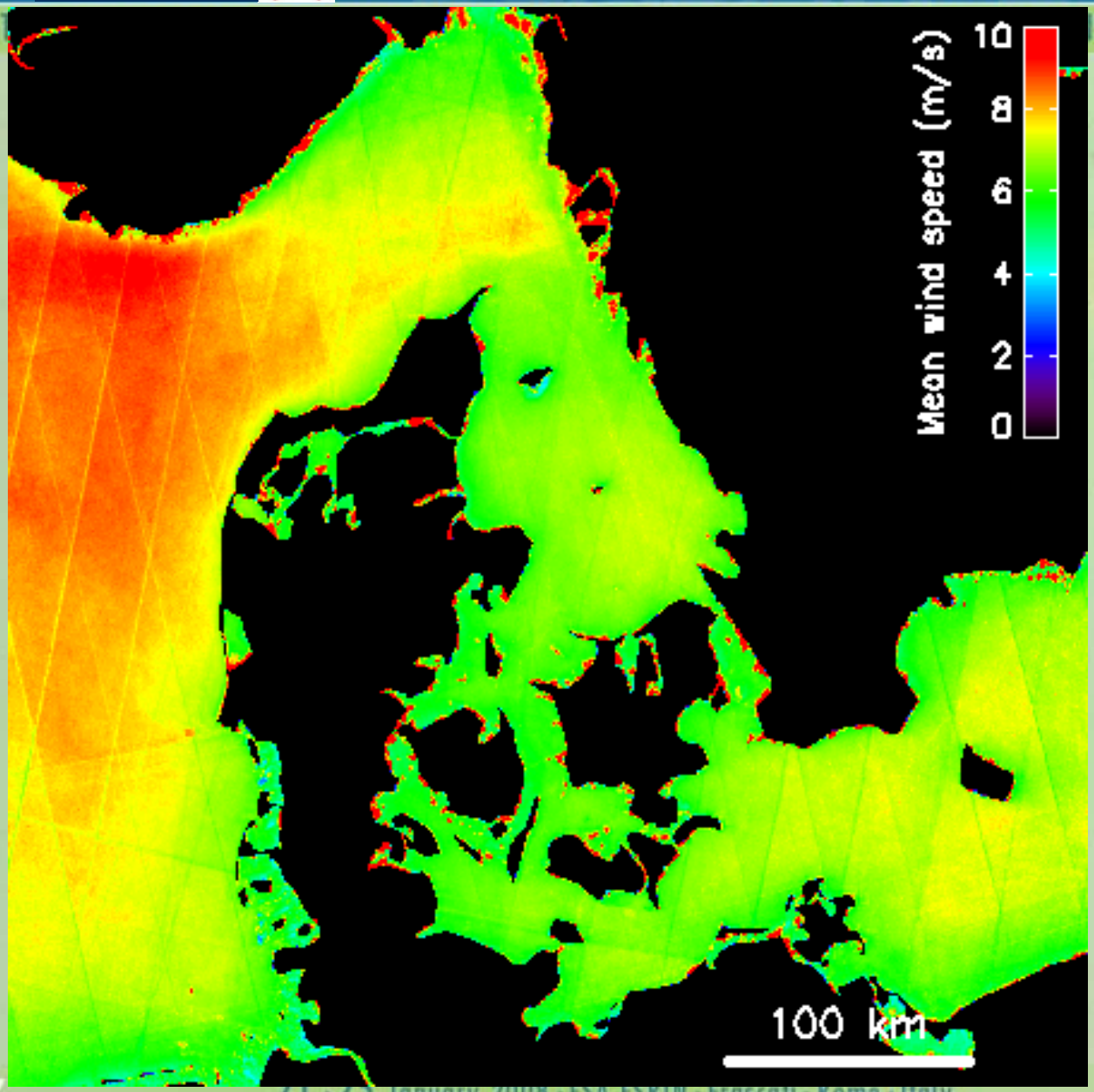
Wind directions from atmospheric model (NOGAPS)

Processsing in near-real-time

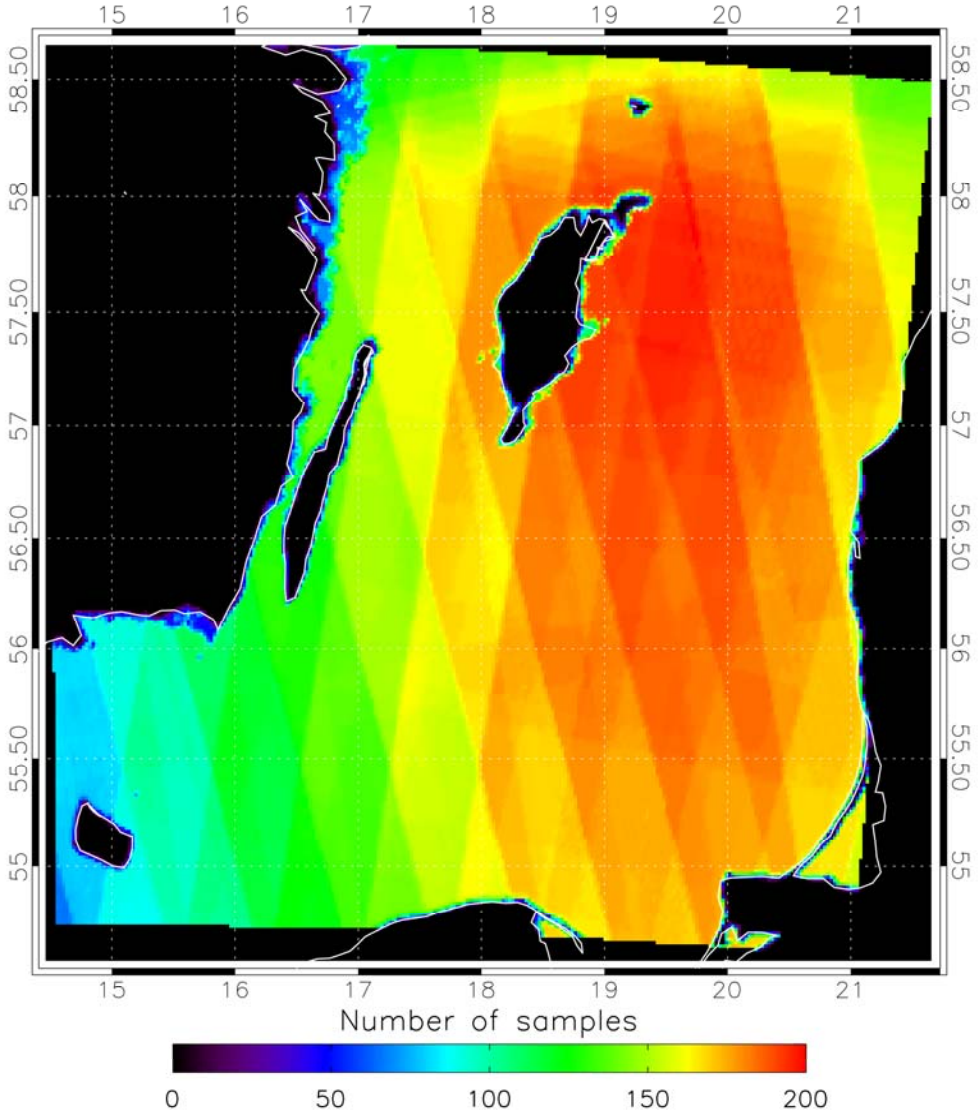
On-line presentation at www.risoe.dk



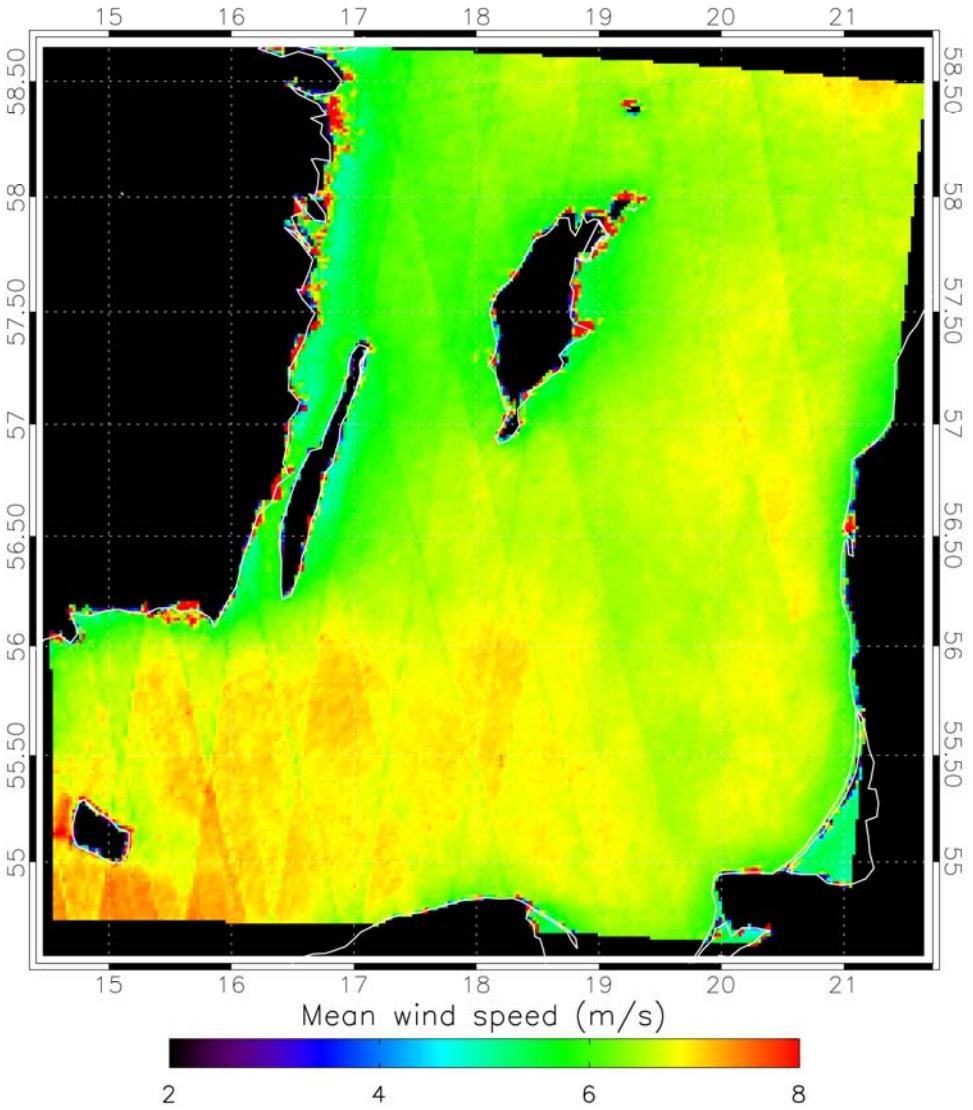

esa
RISØ
DTU
Number of samples
200
150
100
50
0
100 km
MISSIONS
European Space Agency
Agence spatiale européenne
the Living Planet

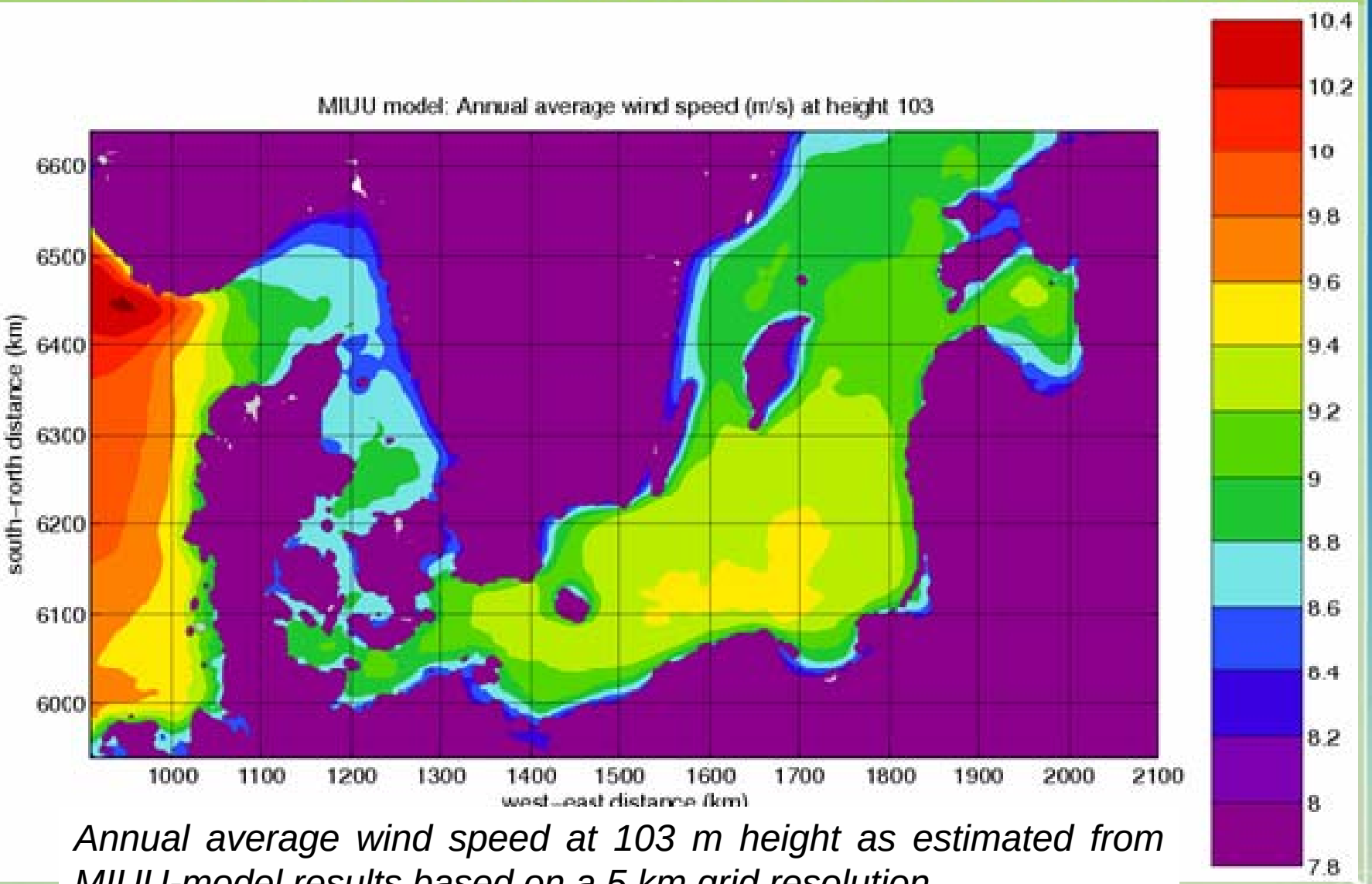

Mean wind speed (m/s)
10
8
6
4
2
0
100 km

Envisat
ASAR WSM
239 maps



Envisat
ASAR WSM
239 maps



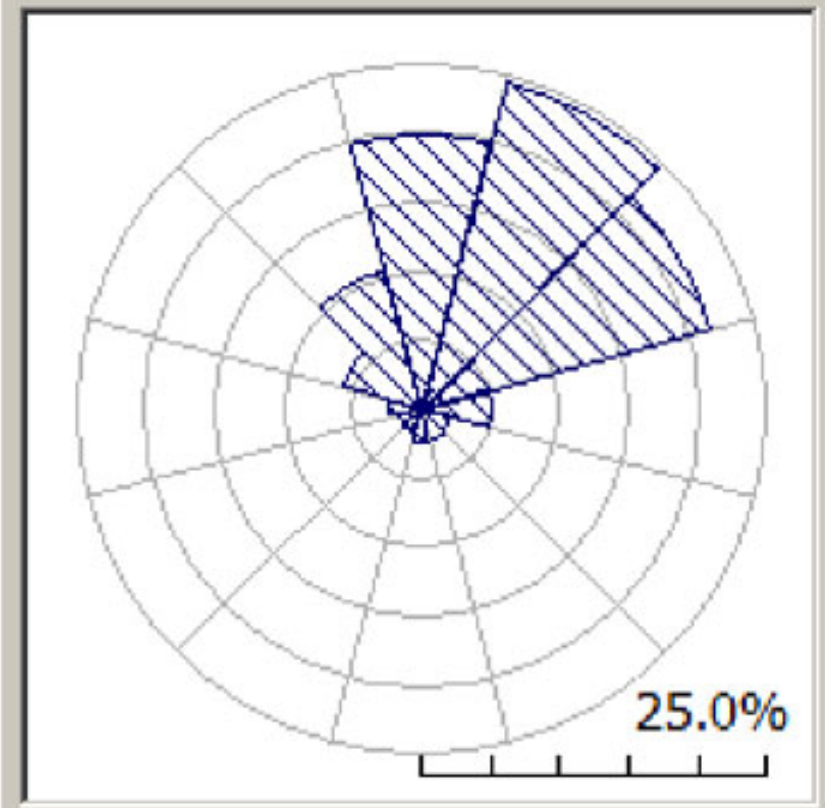


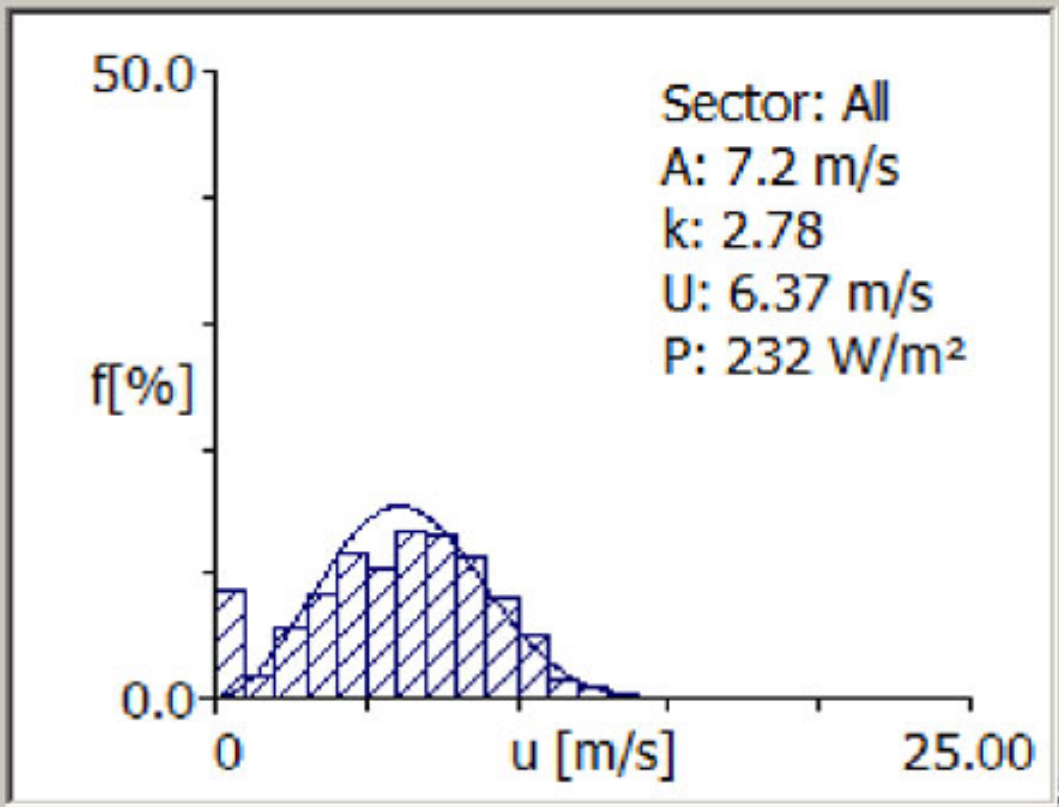
Annual average wind speed at 103 m height as estimated from MIUU-model results based on a 5 km grid resolution.
Courtesy: Hans Bergström, Uppsala University

'Fuerteventura' Observed wind climate

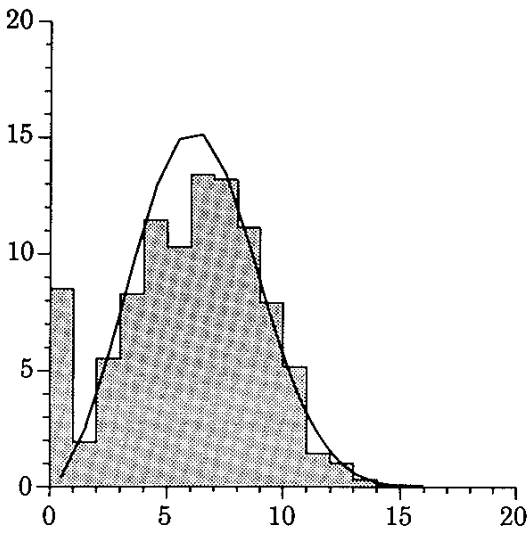
Fuerteventura, Spain, 1972-82

Data from 6 metres a.g.l. Latitude: 28.45, Longitude: -13.85

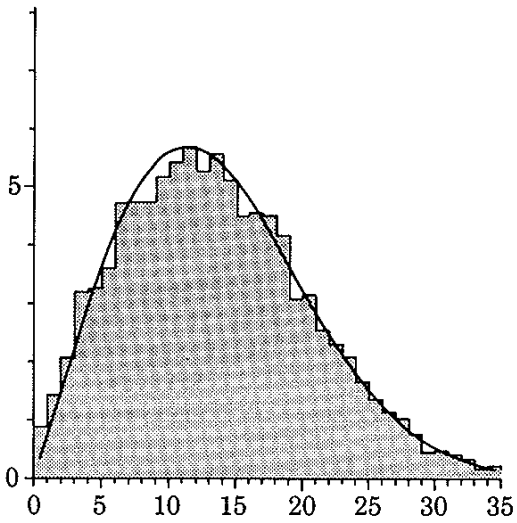




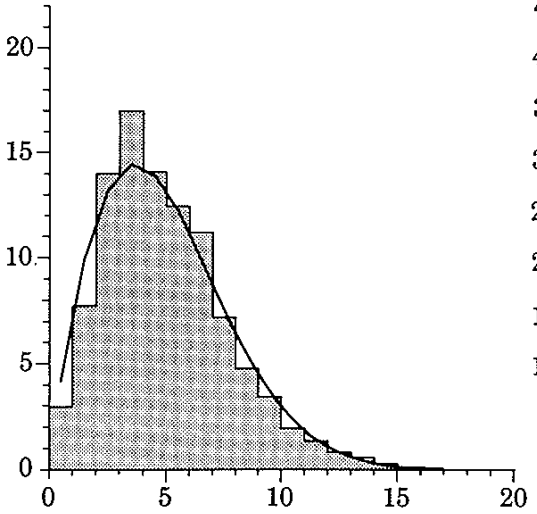
Fuerteventura Canary Islands, Spain
A = 7.2 ms^{-1}, k = 2.78



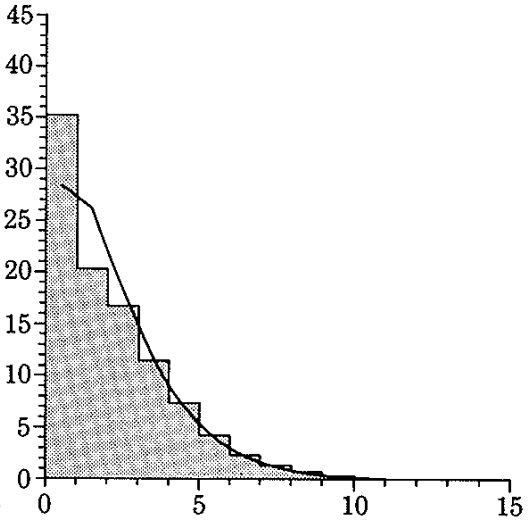
Snaefell, UK
A = 15.4 ms^{-1}, k = 2.08



Schiphol, The Netherlands
A = 5.6 ms^{-1}, k = 1.83



Mont de Marsan, France
A = 2.4 ms^{-1}, k = 1.24



Weibull fitting:

A = scale parameter

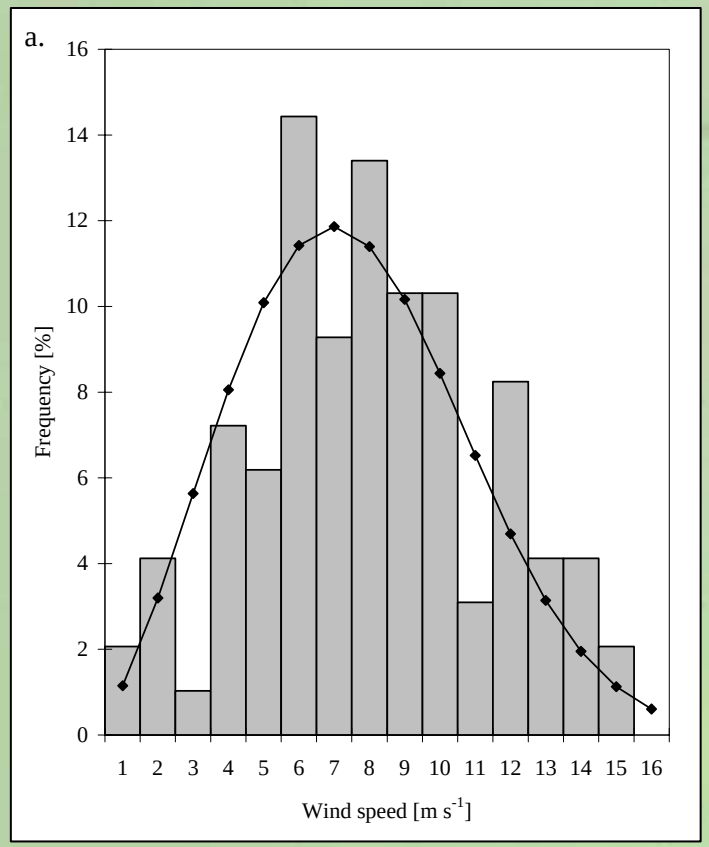
k = shape parameter

From

The European Wind Atlas,

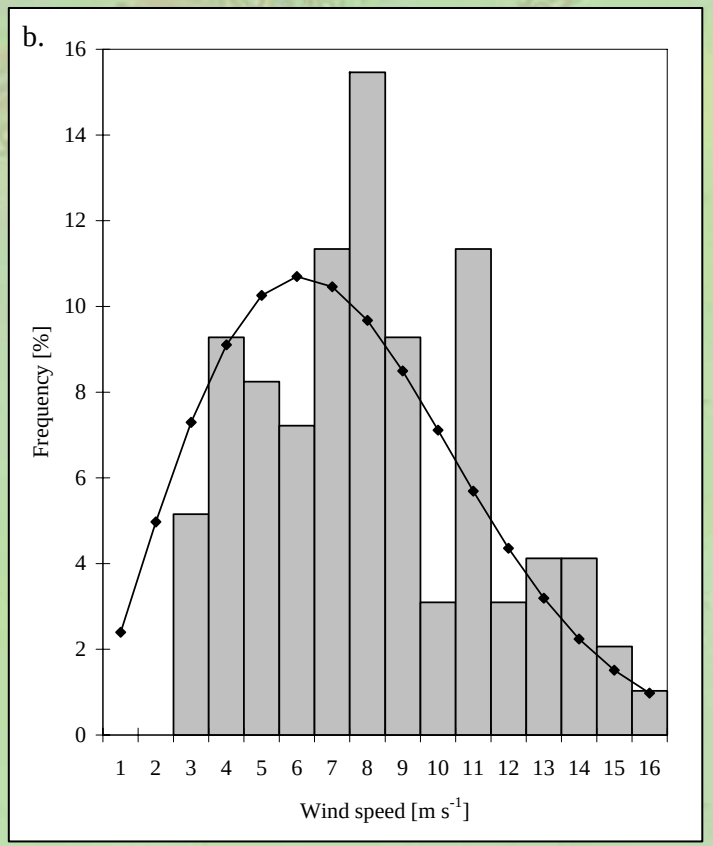
Risø DTU

Meteorological mast wind speeds



U = 7.6 m/s E = 422 W/m^2

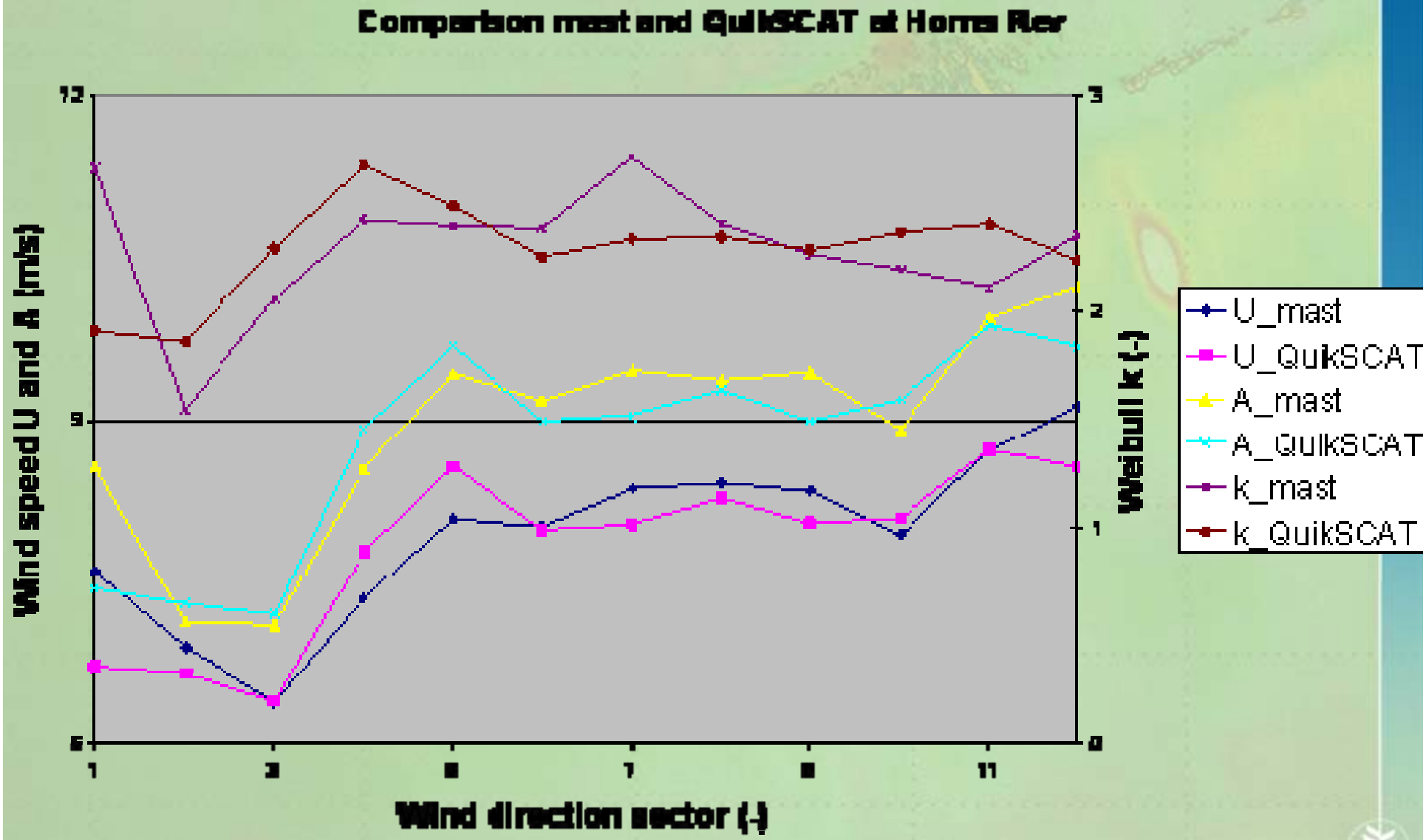
SAR wind speeds



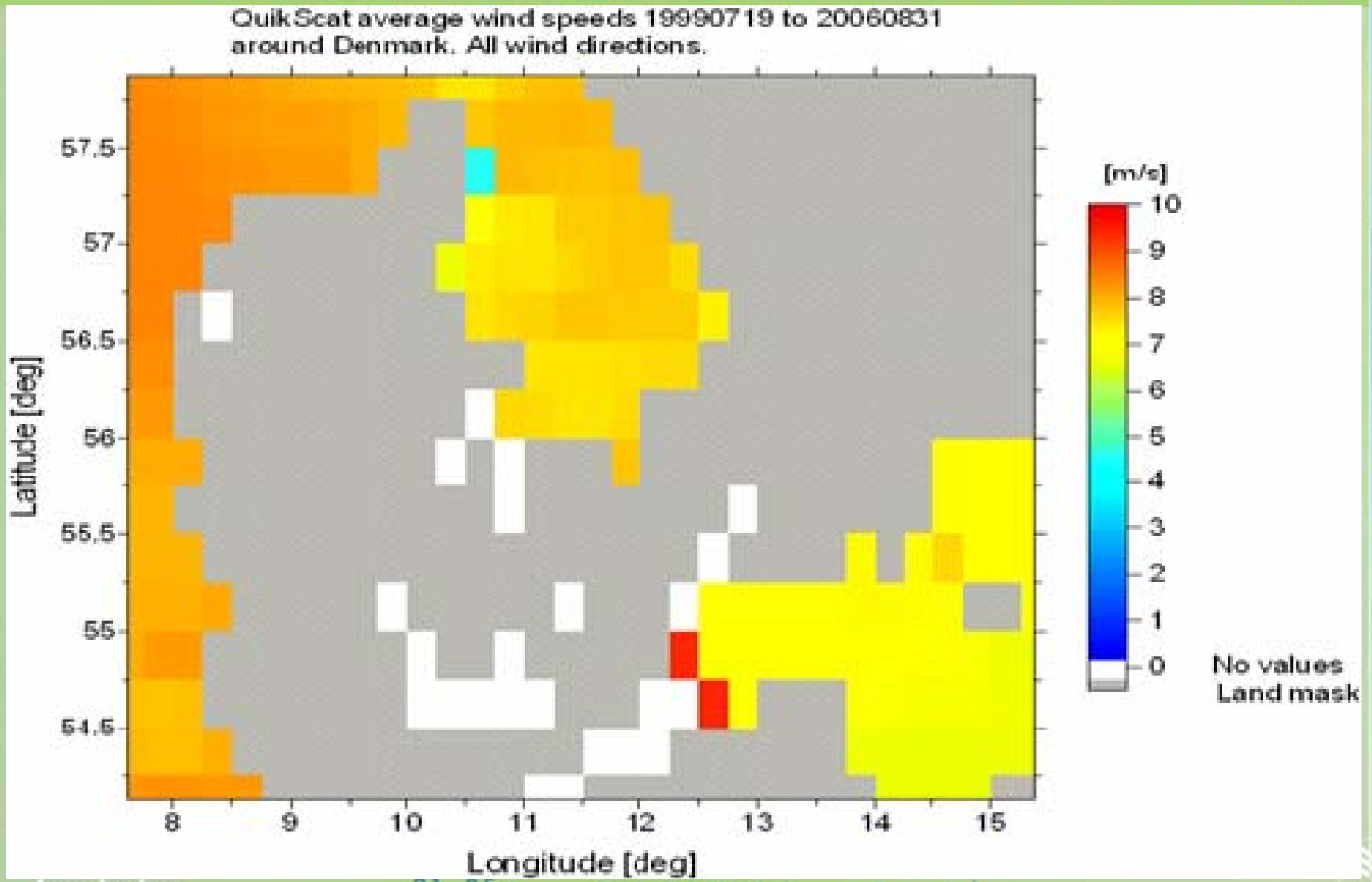
U = 7.3 m/s E = 421 W/m^2

Horns Rev Lightship, 1962-80 (European Wind Atlas): U = 7.3 m/s E = 456 W/m^2

Christiansen et al. (2006): Remote Sens. Env.



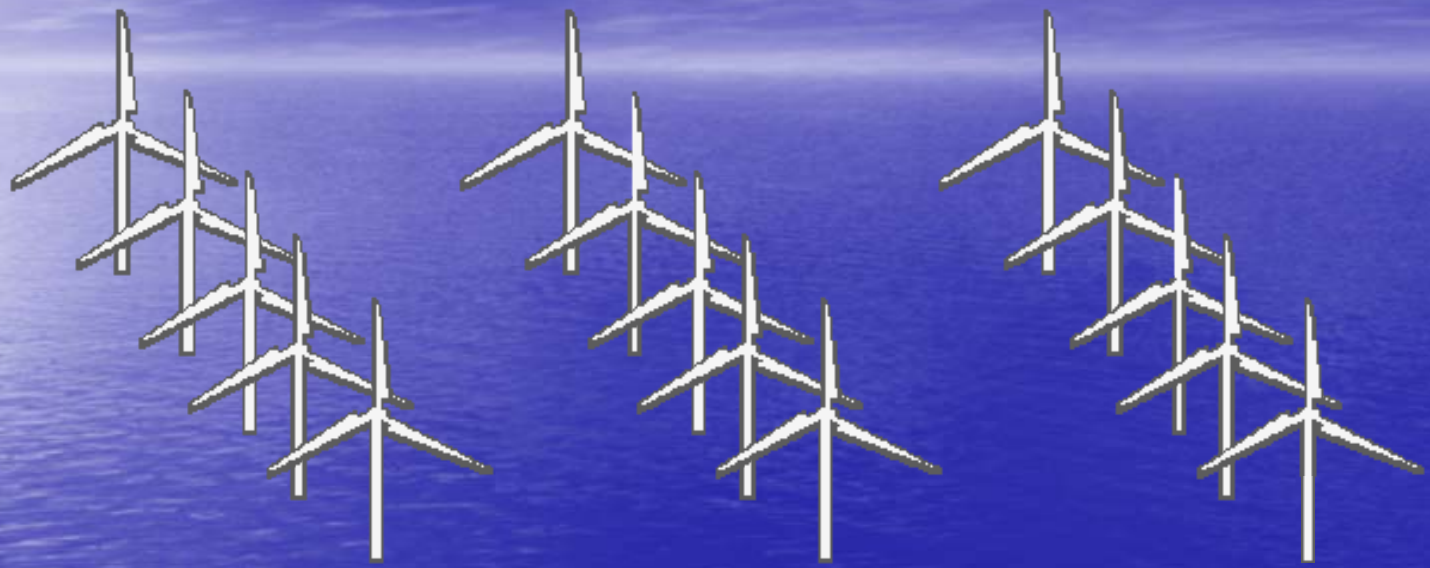
Courtesy of mast data: DONG energy A/S.


QuikScat average wind speeds 19990719 to 20060831
around Denmark. All wind directions.
Latitude [deg]
57.5
57
56.5
56
55.5
55
54.5
8
9
10
11
12
13
14
15
Longitude [deg]
[m/s]
10
9
8
7
6
5
4
3
2
1
0
No values
Land mask

esa RISØ DTU

SEASAR 2008

THE 2nd INTERNATIONAL WORKSHOP ON ADVANCES IN SAR OCEANOGRAPHY FROM ENVISAT AND ERS MISSIONS

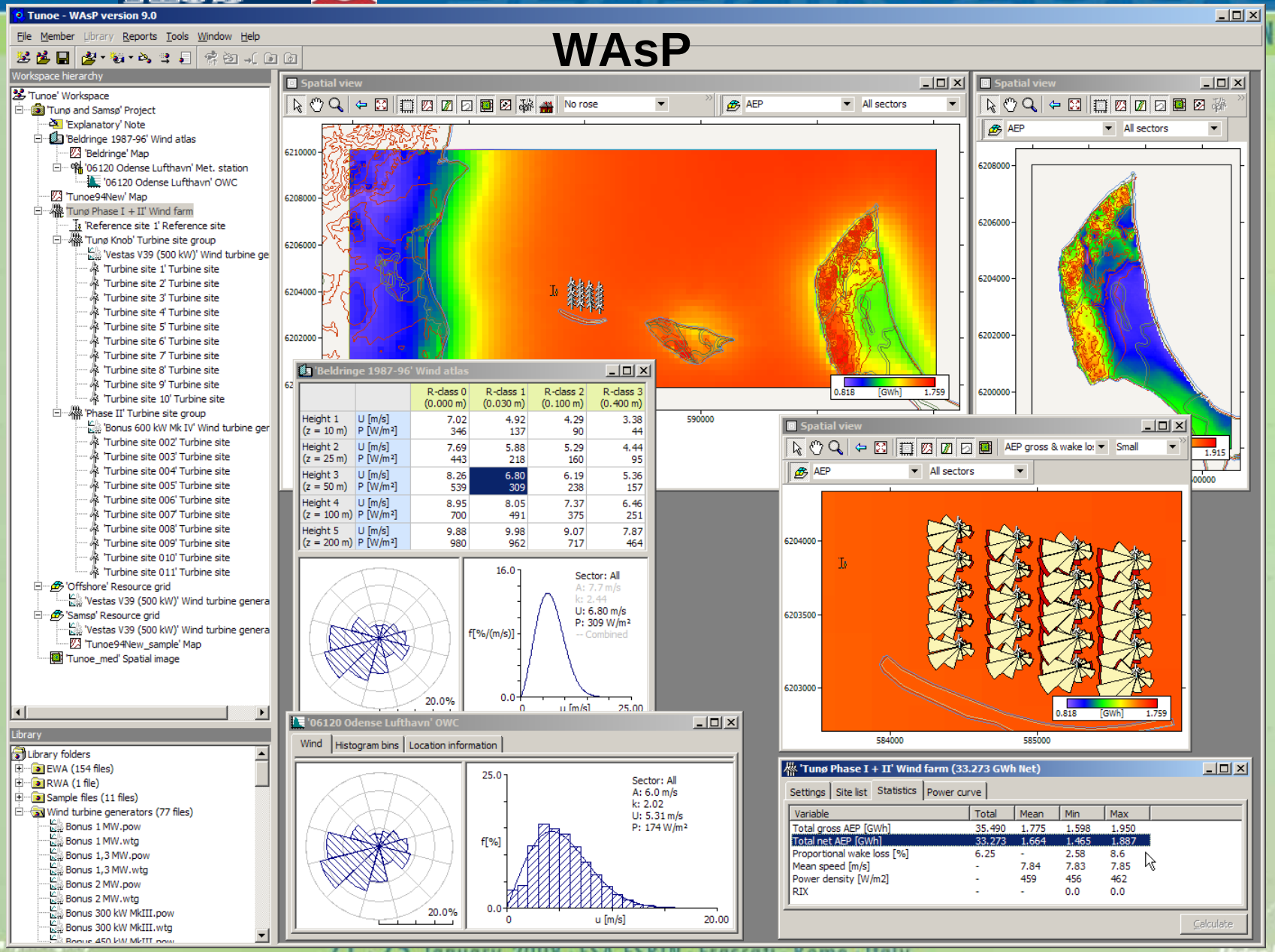


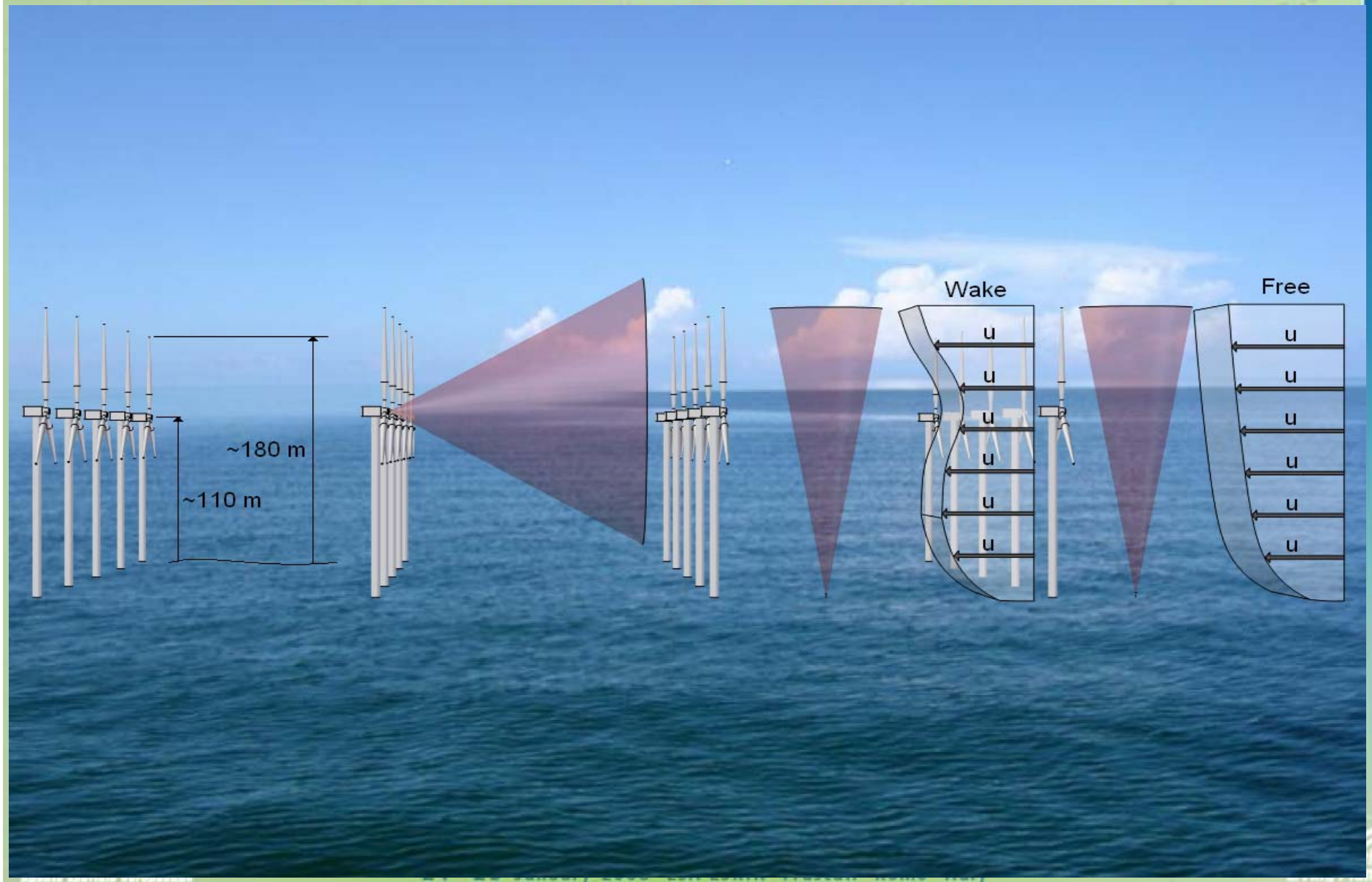
European Space Agency
Agence spatiale européenne

21 - 25 January 2008 - ESA ESRIN - Frascati - Rome - Italy

The Living Planet

WAsP


Tunoe - WAsP version 9.0
File Member Library Reports Tools Window Help
Workspace hierarchy
'Tunoe' Workspace
'Tunø and Samsø' Project
'Explanatory' Note
'Beldringe 1987-96' Wind atlas
'Beldringe' Map
'06120 Odense Lufthavn' Met. station
'06120 Odense Lufthavn' OWC
'Tunoe94New' Map
'Tunø Phase I + II' Wind farm
'Reference site 1' Reference site
'Tunø Knob' Turbine site group
'Vestas V39 (500 kW)' Wind turbine ge
'Turbine site 1' Turbine site
'Turbine site 2' Turbine site
'Turbine site 3' Turbine site
'Turbine site 4' Turbine site
'Turbine site 5' Turbine site
'Turbine site 6' Turbine site
'Turbine site 7' Turbine site
'Turbine site 8' Turbine site
'Turbine site 9' Turbine site
'Turbine site 10' Turbine site
'Phase II' Turbine site group
'Bonus 600 kW Mk IV' Wind turbine ger
'Turbine site 002' Turbine site
'Turbine site 003' Turbine site
'Turbine site 004' Turbine site
'Turbine site 005' Turbine site
'Turbine site 006' Turbine site
'Turbine site 007' Turbine site
'Turbine site 008' Turbine site
'Turbine site 009' Turbine site
'Turbine site 010' Turbine site
'Turbine site 011' Turbine site
'Offshore' Resource grid
'Vestas V39 (500 kW)' Wind turbine genera
'Samsø' Resource grid
'Vestas V39 (500 kW)' Wind turbine genera
'Tunoe94New_sample' Map
'Tunoe_med' Spatial image
Library
Library folders
EWA (154 files)
RWA (1 file)
Sample files (11 files)
Wind turbine generators (77 files)
Bonus 1 MW.pow
Bonus 1 MW.wtg
Bonus 1,3 MW.pow
Bonus 1,3 MW.wtg
Bonus 2 MW.pow
Bonus 2 MW.wtg
Bonus 300 kW MkIII.pow
Bonus 300 kW MkIII.wtg
Spatial view
No rose
AEP
All sectors
6210000
6208000
6206000
6204000
6202000
590000
0.818 [GWh] 1.759
Spatial view
AEP
All sectors
6208000
6206000
6204000
6202000
6200000
1.915
'Beldringe 1987-96' Wind atlas
R-class 0 (0.000 m)
R-class 1 (0.030 m)
R-class 2 (0.100 m)
R-class 3 (0.400 m)
Height 1 (z = 10 m) U [m/s] 7.02 4.92 4.29 3.38
P [W/m²] 346 137 90 44
Height 2 (z = 25 m) U [m/s] 7.69 5.88 5.29 4.44
P [W/m²] 443 218 160 95
Height 3 (z = 50 m) U [m/s] 8.26 6.80 6.19 5.36
P [W/m²] 539 309 238 157
Height 4 (z = 100 m) U [m/s] 8.95 8.05 7.37 6.46
P [W/m²] 700 491 375 251
Height 5 (z = 200 m) U [m/s] 9.88 9.98 9.07 7.87
P [W/m²] 980 962 717 464
20.0%
16.0
0.0
f[%/(m/s)]
u [m/s]
25.00
Sector: All
A: 7.7 m/s
k: 2.44
U: 6.80 m/s
P: 309 W/m²
-- Combined
Spatial view
AEP gross & wake lo
Small
AEP
All sectors
6204000
6203500
6203000
584000
585000
0.818 [GWh] 1.759
'06120 Odense Lufthavn' OWC
Wind
Histogram bins
Location information
20.0%
25.0
0.0
f[%]
0
u [m/s]
20.00
Sector: All
A: 6.0 m/s
k: 2.02
U: 5.31 m/s
P: 174 W/m²
'Tunø Phase I + II' Wind farm (33.273 GWh Net)
Settings
Site list
Statistics
Power curve
Variable Total Mean Min Max
Total gross AEP [GWh] 35.490 1.775 1.598 1.950
Total net AEP [GWh] 33.273 1.664 1.465 1.887
Proportional wake loss [%] 6.25 - 2.58 8.6
Mean speed [m/s] - 7.84 7.83 7.85
Power density [W/m2] - 459 456 462
RIX - - 0.0 0.0
Calculate


~180 m
~110 m
Wake
Free
u
u
u
u
u
u
u
u
u
u
u
u

EWEA

25 YEARS POWERING CHANGE

Wind turbines: growing sizes

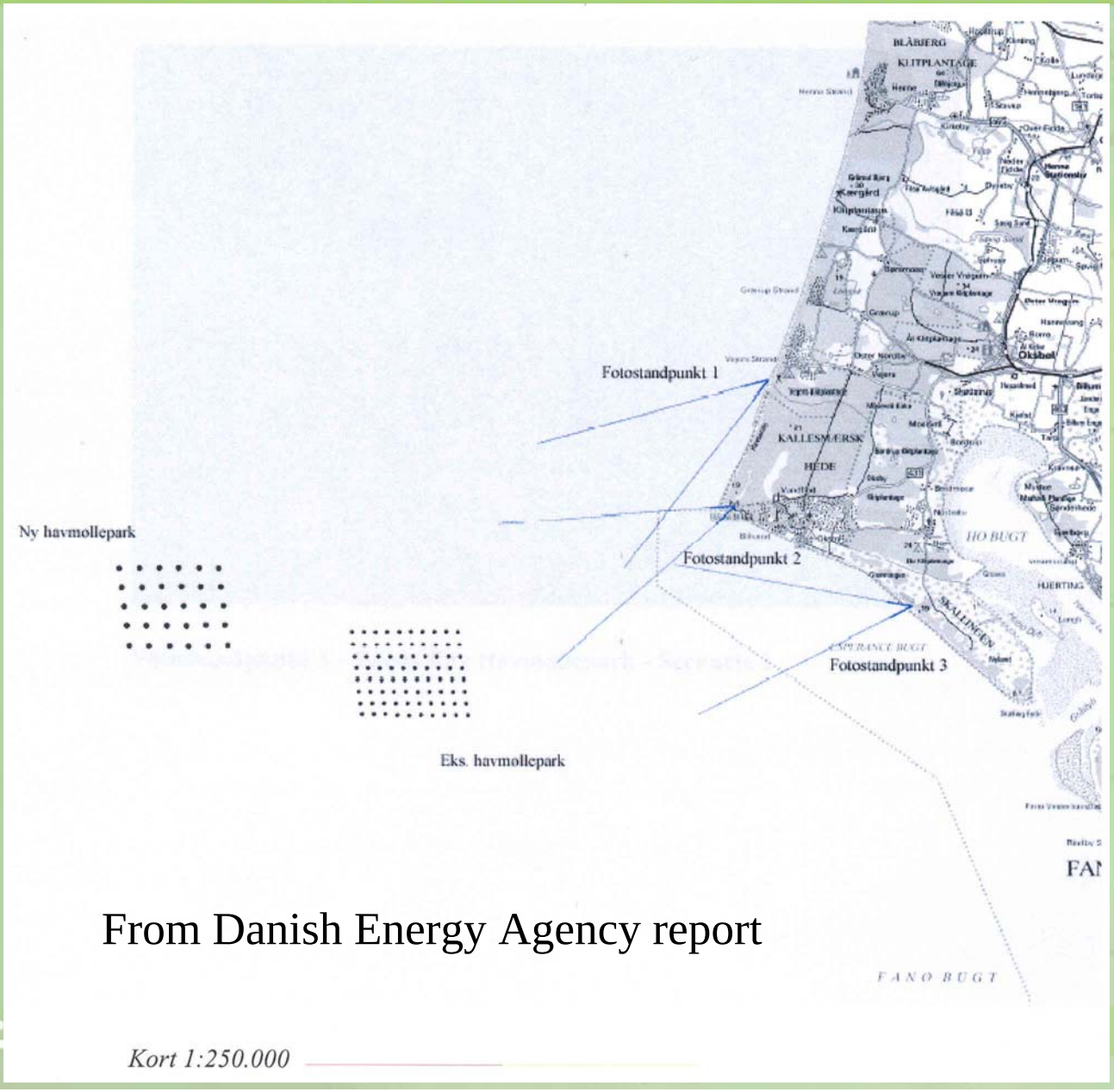
Size of average wind turbine installed in 2006: 1.4 MW (ES) - 1.8 MW (DE)

80% of 2006 market between 1MW and 2.5 MW

Significant height agl: between 100 and 200 m

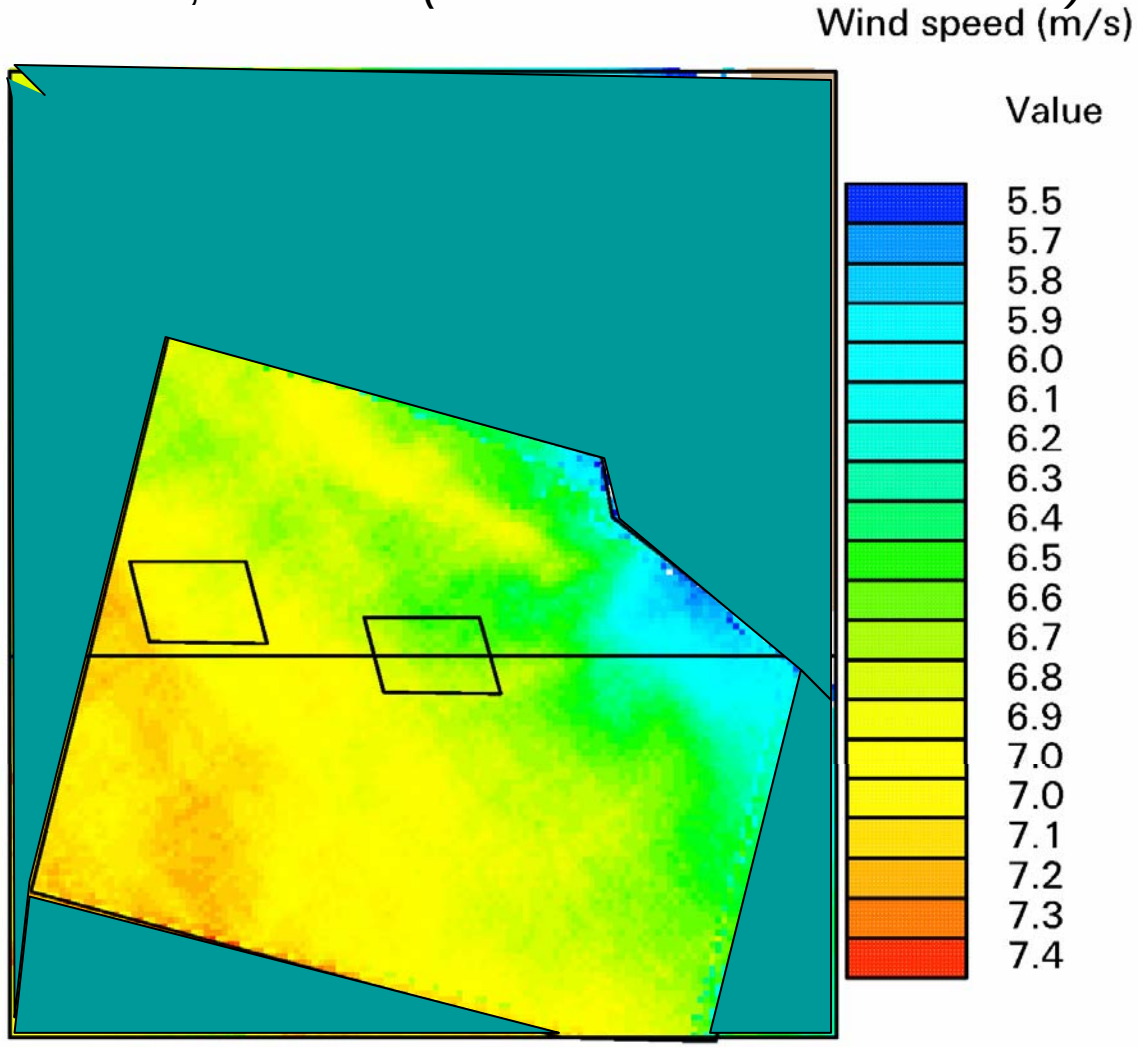
Andrew Garrad, 2006

History of wind

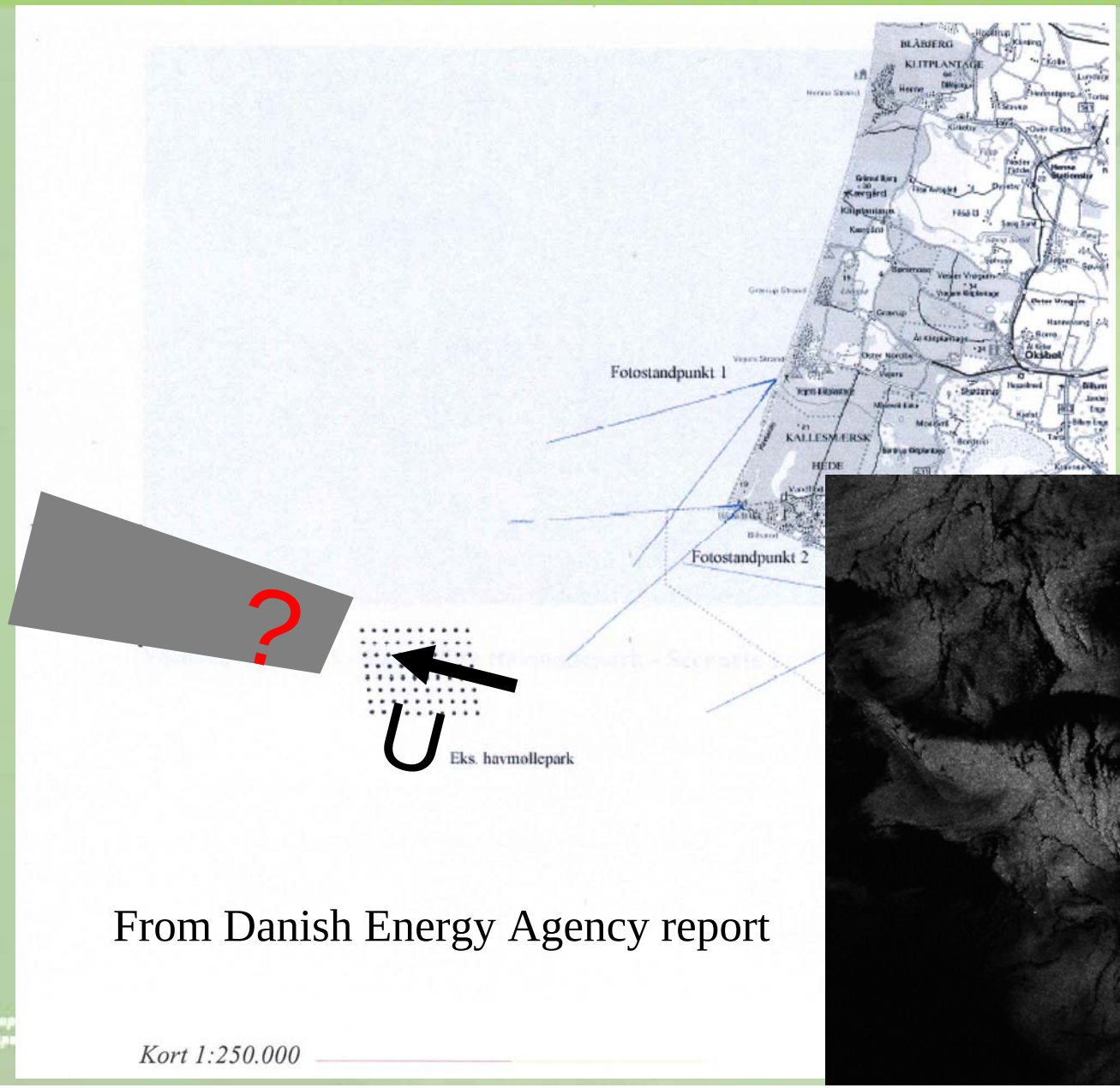


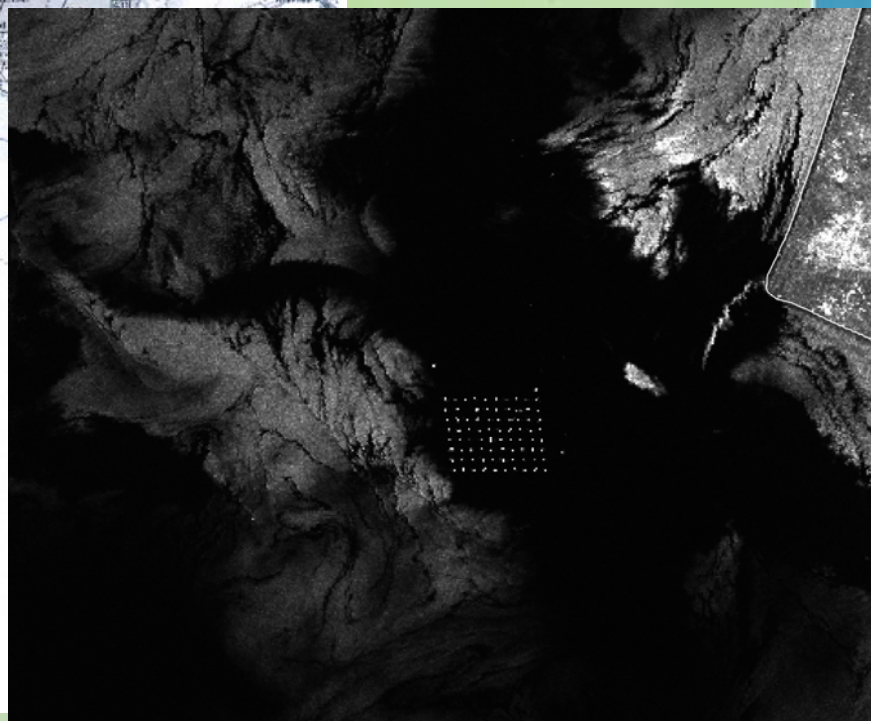
From Danish Energy Agency report

Horns Rev, Denmark *(before wind farm construction)*

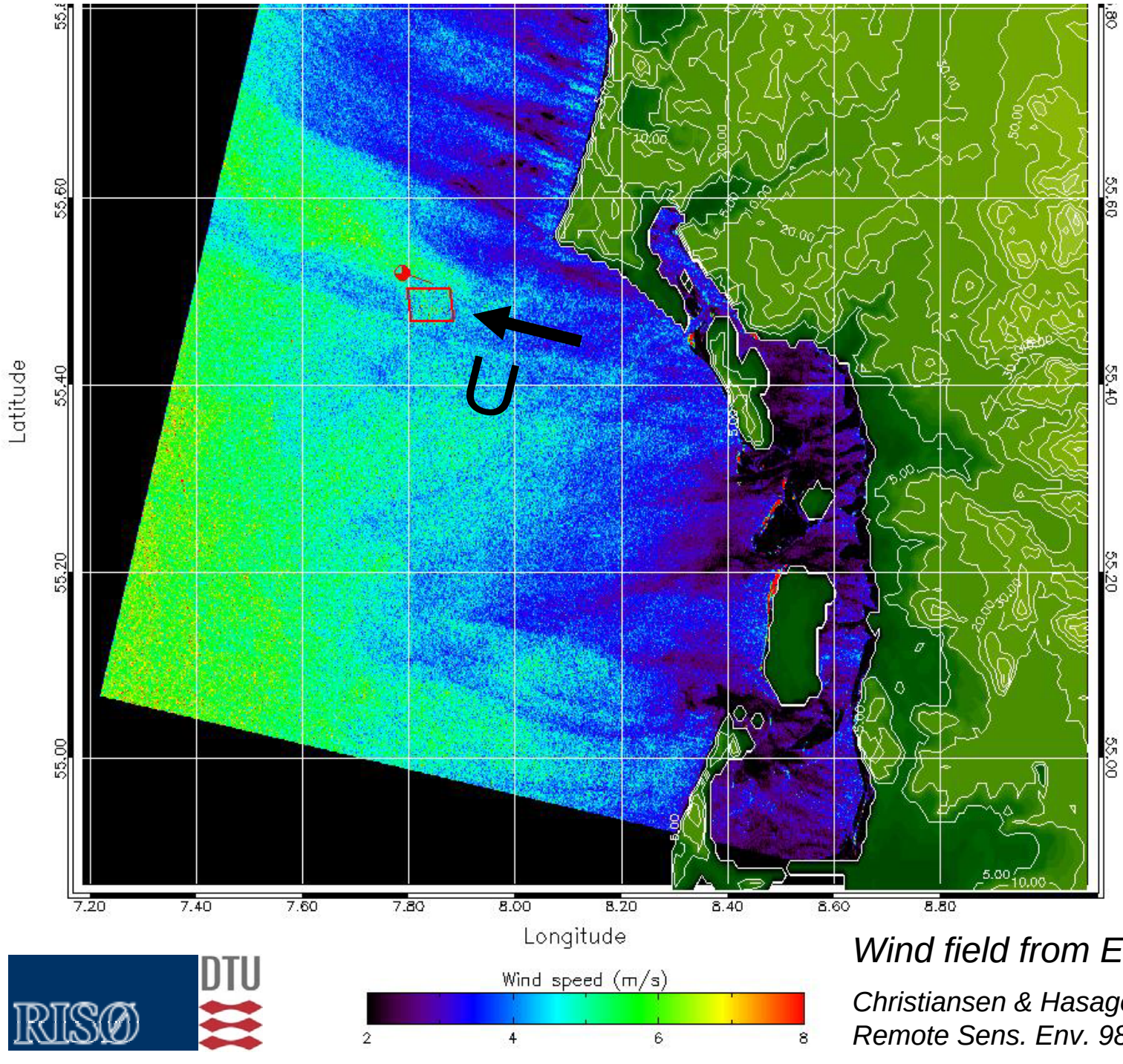


Mean wind speed from 30 ERS-2 SAR wind maps





From Danish Energy Agency report



Wind field from ERS-2 SAR

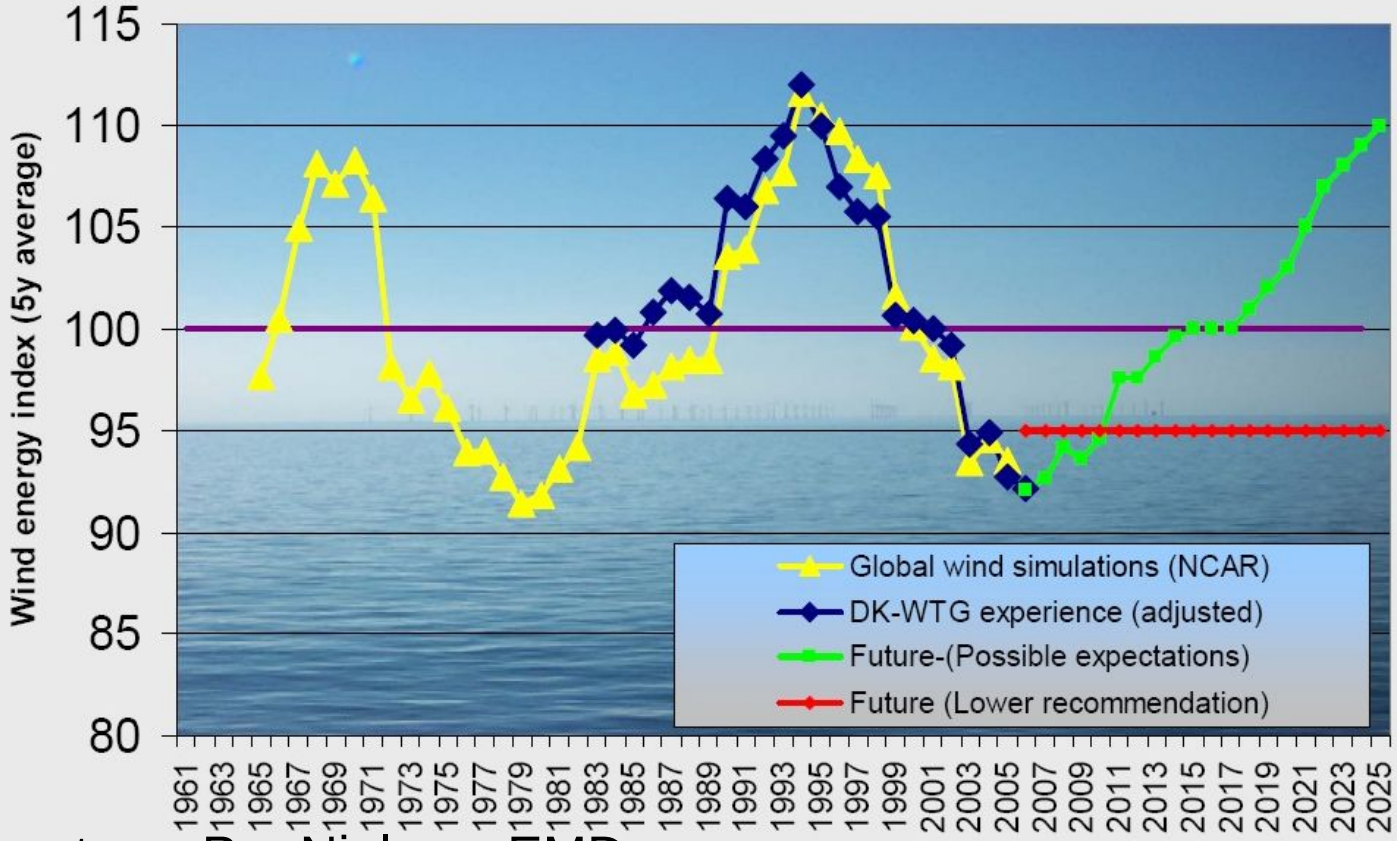
Christiansen & Hasager (2005): Remote Sens. Env. 98, 251-268.

Climate change?

Predict 20 years for business

Wind index variations in Denmark

Wind energy production level in Denmark - based on
EMD-index ver. 2006, adjusted 8% up relative to previous version

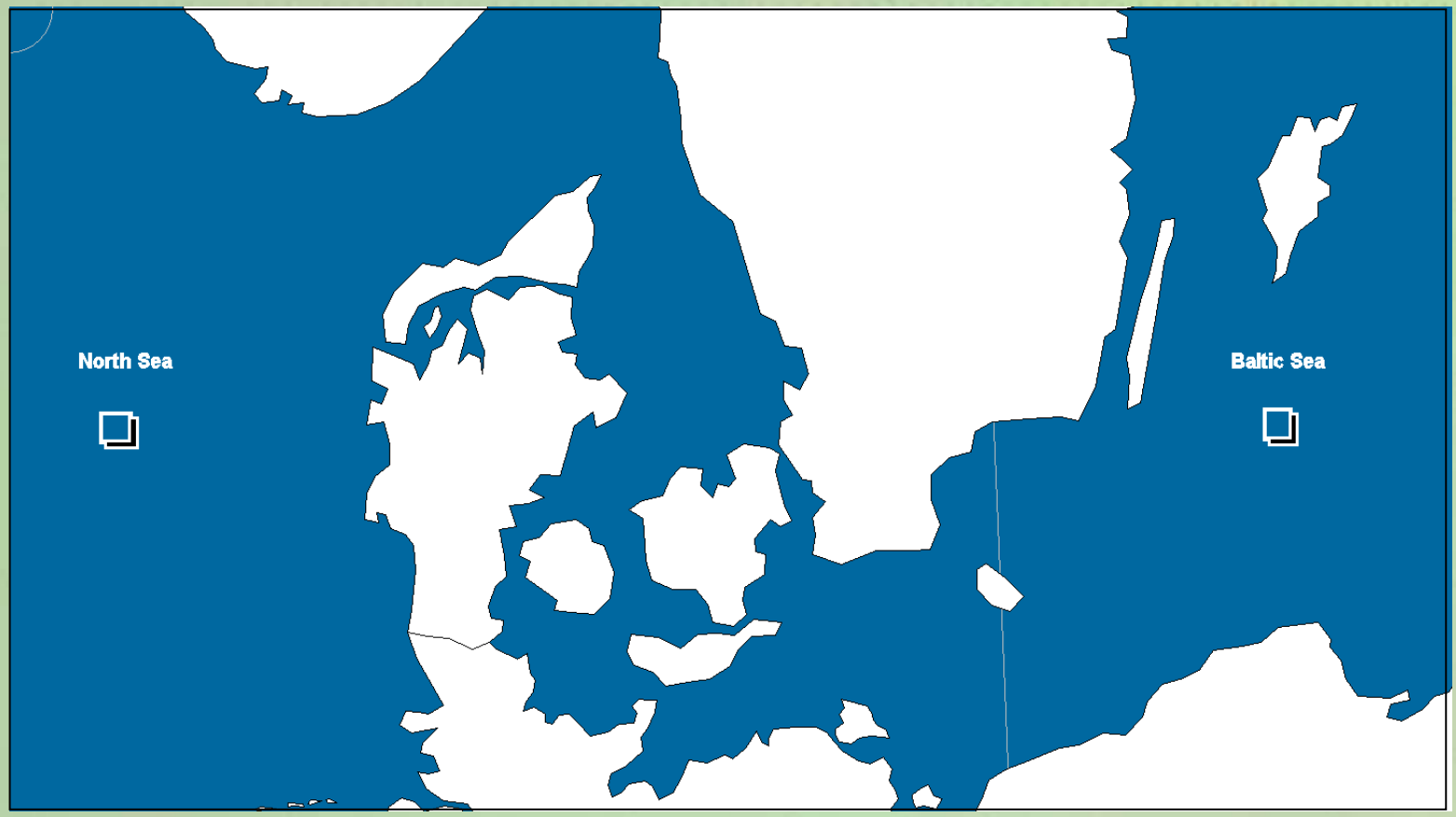


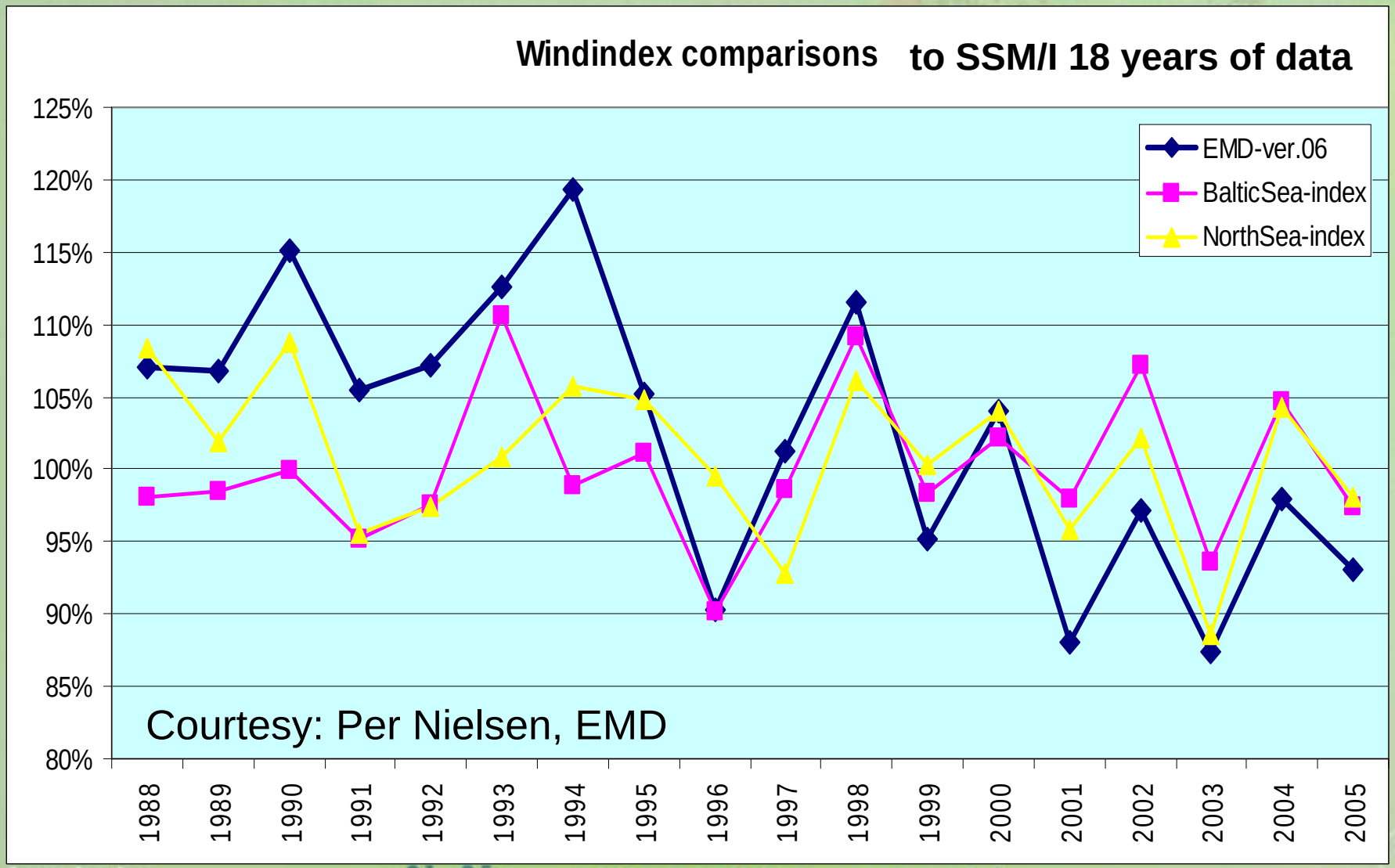
EMD

Courtesy: Per Nielsen, EMD

Wind-index for wind power production

$$Windindex = \frac{Actual\_monthly\_production}{Longterm\_monthly\_production}$$




Windindex comparisons to SSM/I 18 years of data
125%
120%
115%
110%
105%
100%
95%
90%
85%
80%
EMD-ver.06
BalticSea-index
NorthSea-index
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Courtesy: Per Nielsen, EMD

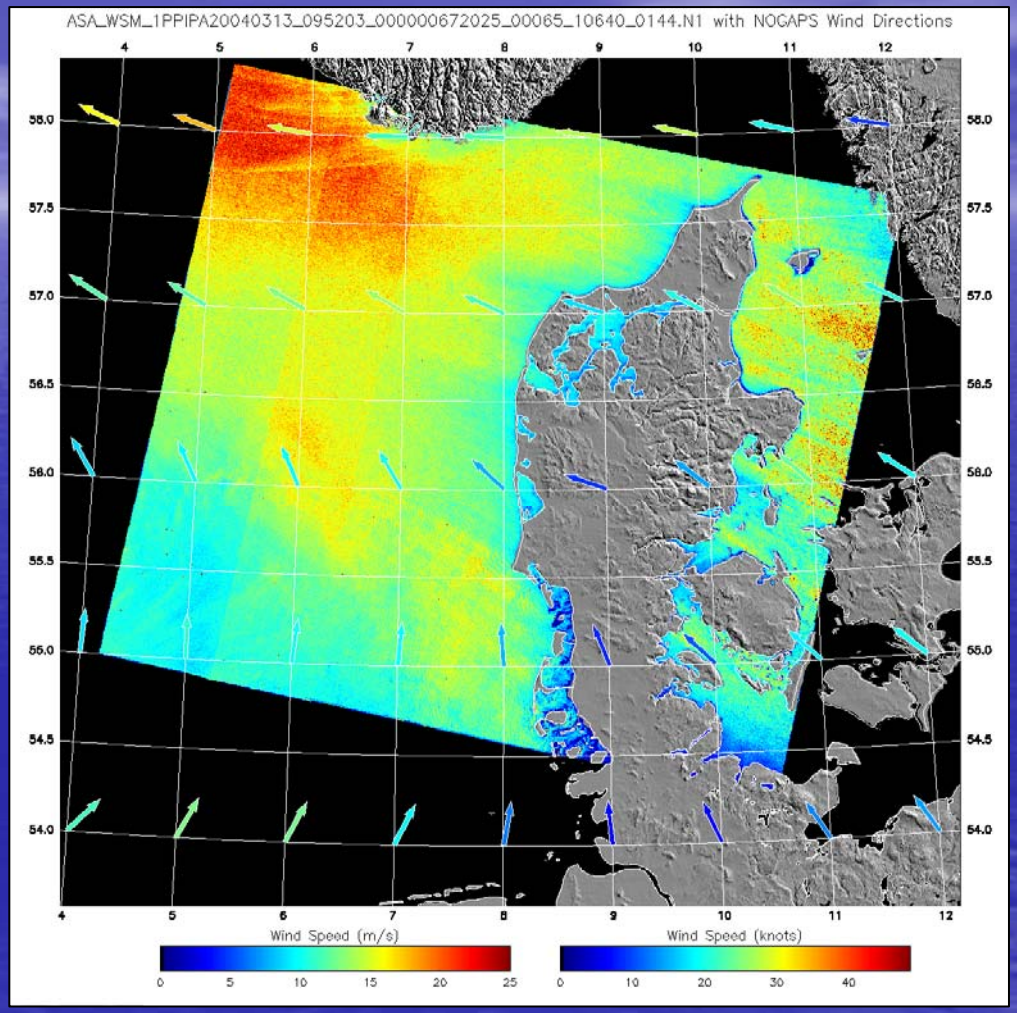
Summary

<u>Advantages:</u>

Mapping spatial variations offshore
Several space platforms
Operational wind mapping

<u>Limitations:</u>

Temporal resolution (improving)
Accuracy (for feasibility acceptable)




Thank you